December 2001 • NREL/SR-500-30934

Subcontractor Report

Philippine Wind Farm Analysis and Site Selection Analysis

January 1, 2000 – December 31, 2000

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Global Energy Concepts, LLC
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1617 Cole Boulevard
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Executive Summary

The U.S. Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL), has been working in partnership with the U.S. Agency for International Development (USAID) in an ongoing process to quantify the Philippine wind energy potential and foster wind farm development. Work to date includes completion of the NREL wind atlas for the Philippines as well as training courses and consultant seminars. A review of the work completed to date indicates that additional activities are necessary to provide the Philippines with the tools necessary to identify the best wind energy development opportunities. In addition, there is a need to review government policies that affect wind energy development and to update previous work documenting the policy changes needed to promote wind energy development.

To meet these needs, NREL retained Global Energy Concepts, LLC (GEC) to review and update the policy needs as well as develop a site-screening process applicable for the Philippines. GEC's assignment included applying the process to sites having apparent wind energy development potential and performing a comparative analysis of the sites. GEC worked closely with the Philippines National Power Corporation (NPC) in completing this work. At the suggestion of NPC and USAID personnel, the work was limited to the central portion of Luzon. The following areas in central Luzon were identified by NPC, visited by GEC, and evaluated with respect to the screening criteria:

- Samploc, Rizal
- Caliraya, Laguna
- Sual, Pangasinan
- Pantabangan, Nueva Ecija
- Puncan-Digdig, Nueva Ecija
- Carranglan, Nueva Ecija

The two areas that achieved the highest rankings are to the north of Carranglan and south of Sual. These areas were not actually visited by GEC, but were evaluated based on the site visits to similar terrain in the vicinity and the NREL wind atlas assessment of the wind resource. These sites do not have the highest estimated wind resource of the sites evaluated; however, their terrain is considerably more conducive to wind project development than the areas with a higher estimated wind resource.

One common theme underlying the screening process of all sites is the lack of quality measured wind speed data. NREL's wind atlas is a very good starting point for locating areas and assisting in the assessment of wind energy potential; however, it should not be the only resource used. On-site wind speed measurements should be made at multiple sites to provide a more accurate assessment of the wind resource potential at these sites and, as a secondary goal, to refine the results of the wind atlas. In addition, a disciplined review of the NREL wind atlas, the Philippine highway and transmission system, and the site evaluation methodology developed herein should be applied to other areas of the Philippines to identify additional areas with wind energy development potential.

The review of government policies indicated that several changes have been implemented to support wind energy development. These changes have improved the policy environment for wind energy; however, uncertainty related to deregulation still remains in the energy market. In addition, the power capacity surplus in the Philippines still exists, meaning that there may be less motivation to increase the use of renewable energy resources.

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1 Introduction

The U.S. Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL), has been working in partnership with the U.S. Agency for International Development (USAID) in an ongoing process to quantify the Philippine wind energy potential and foster wind farm development. Work to date includes completion of the NREL wind atlas for the Philippines, as well as government staff participation in numerous training courses and consultant seminars. A review of the work completed indicated that additional activities are necessary to provide the Philippines with the tools necessary to identify the best wind energy development opportunities and generate government policies that would support wind energy development.

1.1 Background

The completion of the Wind Energy Resource Atlas of the Philippines by NREL is a significant step in quantifying the wind energy potential. Considerable additional effort is still necessary, however, to fill the gap between knowing the estimated wind resource from the atlas and completing the development of a utility-scale wind energy facility. To date, the Philippine National Oil Company (PNOC) is the only entity that has completed the process, having completed site selection, rigorous wind resource measurement, negotiation of environmental permits, and acquisition of local government approvals. The first phase of their project is a 42-MW installation near Bangui in the province of Ilocos Norte. PNOC envisions future expansion of the project to 100 MW. Expanding the number of organizations that understand the issues critical to project development and how they affect site selection will facilitate further development of wind energy in the Philippines, as will development of government policies conducive to wind energy project development.

To meet these needs, NREL retained Global Energy Concepts, LLC (GEC) to develop a site-screening process applicable for the Philippines, apply the process to sites having apparent wind energy development potential, and perform a comparative analysis of the sites. The intent of this effort is to develop and document a process that can be used by subsequent developers and government agencies interested in identifying the most likely areas for placement of wind turbines. GEC was also asked to review the current government policies and identify areas that need changes in order to support wind energy development.

1.2 Purpose and Scope

The objective of this work is to provide a mechanism for ranking and prioritizing potential utility-scale wind energy sites in the Philippines and to identify policy changes needed to better support development of Philippine wind energy resources. To meet this objective, GEC developed a site-screening process that could be used to evaluate relatively large areas being considered for utility-scale wind energy development. The application of the process was demonstrated for several sites in central Luzon that were selected by the Philippines National Power Company (NPC) and inspected by GEC and NPC personnel. GEC worked closely with NPC personnel to develop and apply the evaluation methodology.

The focus of GEC's work was primarily on the technical issues associated with evaluating sites for potential wind farm development. Policy issues identified in the course of discussions with stakeholders have been included in this report; however, they are not the focus of discussion. Further details related to policy issues are presented in a previous NREL report prepared by consultant Kevin Rackstraw. An update on the current status of government policies as they relate to wind energy development was completed by Mr. Rackstraw as part of this work and is included in appendix A.

1.3 Report Organization

This report is divided into five sections and appendixes. After this introductory first section, the site-screening process is presented in section 2. Section 3 briefly describes the activities performed by GEC while in the Philippines and identifies various government agencies, companies, and people with whom meetings were held to gain insights into issues unique to the Philippines. The results of the site inspections and application of the screening criteria are presented in section 4. Section 5 summarizes the results of the work and presents a comparative analysis of the sites. It also identifies areas of interest for further evaluation and makes recommendations concerning meteorological tower installation for monitoring the wind resource on the site. Appendix A provides a description of government policies as they relate to wind energy development. Appendix B presents the rankings of Philippine provinces with respect to frequencies of typhoon and tropical storm occurrences. Appendixes C and D contain GEC's photo log of the site visits.

2 Site-Screening Process

To provide a mechanism for ranking and prioritizing potential utility-scale wind energy sites in the Philippines, GEC developed a site-screening process to evaluate relatively large areas. The process is intended for use in siting commercial, utility-scale wind energy facilities. Smaller facilities providing energy for rural and/or off-grid development applications are not specifically addressed in this process.

The screening process was developed based on techniques used in the United States and adjusted for application in the Philippines. A preliminary version of the screening process was provided to the NPC for review prior to GEC's trip to Manila. Adjustments to the criteria content were made based on NPC's review, in particular the inclusion of facility security issues and social acceptability of the project. Additional information was obtained during meetings with stakeholders in Manila (discussed further in section 3) that further refined the criteria. All adjustments to the original criteria developed by GEC have been incorporated in the information presented below.

The result of this work is a five-step process that addresses wind resource evaluation, evaluation of land suitability, analysis of site-specific suitability, preliminary site ranking, and quantitative analysis. The following sections discuss each step in more detail.

2.1 Step 1 Initial Screening of Wind Resource

The most important factor in selecting a wind energy site is the wind resource itself. A review of the NREL wind resource atlas for the Philippines indicates that there is a significant wind resource. It is present in very discrete areas of the country, typically at higher elevations within mountainous regions. Therefore, the first "screen" is to eliminate all sites that are not expected to have a sufficient wind resource. Many factors can be considered in the wind resource assessment process, including:

- NREL wind atlas
- Local meteorological data
- Local "common knowledge"
- Biological and physical indicators.

At the present time, the most comprehensive assessment of the Philippines wind energy resource is the NREL wind atlas. In the absence of local data and/or information to the contrary, all areas that are not ranked as "good" or better for utility applications [corresponding to a wind power density between 300-400 W/m^2 at 30 m (98 ft) height] by the NREL wind atlas should not be considered for utility-scale wind energy development. Note that a site's specific terrain features, vegetation, and exposure will significantly affect the wind resource. As a result, many sites within areas ranked good or better in the NREL maps may not actually have wind resources at the levels indicated. Conversely, some sites identified as having a less than good resource on the NREL maps may actually have resources that are significantly better. These areas can be identified through interpretation of local data and knowledge.

Within the areas defined as good or excellent by the NREL wind atlas, sites that are well exposed to the prevailing wind conditions should be identified. These are often ridgelines or other high-terrain features. In some areas, mountain passes may have a strong wind resource, and they are more likely to have roads and transmission lines than ridge crests. Therefore, even if the passes themselves are not identified as high-wind resource areas, ridge crests protruding into the passes may offer an acceptable wind resource and relatively convenient access to the electrical grid and transportation system.

While the on-site wind resource assessment program will determine the wind resource on a site during the measurement period, gaining confidence in the true long-term average wind resource requires multiple years of wind data. One approach to increasing confidence in the true long-term average wind speed at the site is to correlate on-site measurements with a long-term reference station exposed to similar climatological conditions. Long-term stations can often be found at airports, universities, military installations, pollution monitoring stations, and similar facilities. The proximity to a suitable long-term reference station should be a factor in the site selection process, particularly if there is a desire to develop the project within the next three years.

An additional criterion is assessing the quality of the available wind data. Factors that affect data quality include the quality of the measurement equipment, the height and exposure of the anemometer to the higher elevation wind speeds, the recording methods used, and a successful data capture rate. Newer equipment in good condition will give higher confidence than older equipment, and electronic recording is normally better than manual recording because data are captured continually with no subjective bias.

For on-site measurement equipment, it is important that the airflow be clear of obstructions, such as trees and buildings, and that the height is adequate to assess wind speeds at typical wind turbine heights [50 m (164 ft) or more for current utility-scale turbines]. For data from a reference site, one of the more important concerns is that the measurements have been taken consistently from the same location for several years. Changes in location or measurement equipment make correlations difficult to assess with confidence.

2.2 Step 2 Initial Screening for Land Suitability

All land with a good or better wind energy resource may not be suitable for wind energy development. An initial land suitability screening will eliminate sites where wind turbines either cannot or should not be installed. Factors that would eliminate a site from consideration include:

- National parks or other areas officially protected from development
- Migration routes of migratory bird species
- Areas with high concentrations of rare or endangered birds
- Urban areas
- Some military areas
- Highly culturally sensitive areas (e.g., religious, historic, or archeological sites).

These areas should be eliminated from consideration for wind energy development. Other site suitability issues are addressed by the next step in the process. In addition, sites should be subjected to an initial screening for transportation and transmission access. This can be accomplished by overlaying the NREL wind atlas on the transmission and road network to identify areas with a strong wind resource and good transportation and transmission access.

2.3 Step 3 Evaluate Factors Affecting Site Suitability

There are many factors that affect site suitability. Those factors that will affect the costs and performance of a project and must be considered in the site selection process are discussed below.

2.3.1 Proximity to Transmission Lines (Grid Accessibility) and Required Transmission Upgrades

Having a good wind energy resource will only be beneficial to a project's developers if the energy generated by the project can be delivered to the purchaser in a cost-effective manner.

It is usually physically possible to interconnect a site to a transmission system. However, the costs of such interconnections can be prohibitive. Maps of the Philippine transmission system should be overlaid on the wind resource maps to identify areas where there is a wind resource, proximity to the transmission system, and capacity on the transmission system to take the energy from a wind project to the loads.

Other factors to consider in the evaluation of transmission options include whether or not transmission lines with insufficient capacity to support a project can be upgraded through the use of new conductors, or if alternative transmission paths can be arranged to open space on the lines. The stability of the transmission system at the project interconnection point also needs to be considered. If the grid is subjected to frequent outages or voltage/frequency excursions, then the energy production from the site will be reduced.

Ultimately, it may be necessary to conduct a complete load flow study of the wind energy project interconnected to the transmission system, but this is not needed until later in the process of finalizing site selection.

2.3.2 Site Terrain, Accessibility, and Complexity

The more remote and/or complex the terrain, the higher the development cost is likely to be. This is because more complex terrain will require more grading and earth movement than less complex terrain. Complex terrain may also limit the size of turbines that can be installed due to limitations in the ability to get the turbines or cranes to the site or to create sufficient lay-down areas for site construction. It can also lead to less-than-optimal turbine siting because terrain features affect the project layout.

The proximity of the site to access roads is also a consideration. Construction of access roads suitable for installation of a wind power plant can be expensive if long sections of new road are required or if the terrain is highly complex.

2.3.3 Terrain Orientation to Prevailing Wind

The orientation of the terrain features relative to the prevailing wind directions will heavily affect the site's capacity potential as well as its energy production. If the terrain features are conducive to a project layout that maximizes the number of turbines exposed to the prevailing winds while minimizing the array loss effects, then the site will have greater capacity and energy production than would otherwise be possible. For example, ridgelines that are perpendicular to the prevailing wind direction are preferred to ridgelines that are parallel to the prevailing wind direction. At sites with no clear prevailing direction, ridgelines limit the capacity that can be installed due to larger turbine-spacing requirements than for sites that have a prevailing wind direction.

Wind turbines are typically arranged in rows perpendicular to prevailing winds. Within rows, the spacing can vary from 1.5 to 5 times the rotor diameter. Row-to-row distances typically vary from 10 to 20 times the rotor diameter. If the wind is consistently from one direction (or the opposite compass direction), then within-row spacing is less and row-to-row spacing is greater. For sites that have energetic winds from multiple directions, the row-to-row spacing and within-row spacing are similar.

2.3.4 Landowner Concerns and Social Acceptability of Wind Energy Development

If the landowners for the site under consideration, or the owners of adjacent land, are opposed to wind energy development on the site, the costs of development may increase significantly and the time required for project completion can also increase. Frequently, opposition to wind project development is based on incorrect information concerning the technology and when fully and accurately informed, development opponents become project supporters. The use of open forum informational meetings to obtain public input is suggested.

2.3.5 Cost of Land

Developing a project depends on having the rights to install turbines on the land. Land control usually is either obtained through a land lease agreement or outright purchase of the land. The relative costs of land control must be considered when comparing project sites.

2.3.6 On-Site Vegetation

Vegetation increases the turbulence intensity at the site and decreases the wind speeds. While modern wind turbine towers are on the order of 50 m (164 ft) in height, the blade passage height can be 25 m (82 ft) or even less. To place the turbines in areas with substantial vegetation over 10 m (33 ft) in height increases the risk of turbulence-induced damage to the turbines or increases project development cost and the environmental impact of the project.

2.3.7 Soil Conditions

Wind turbine foundations are typically reinforced concrete blocks or cylinders. The most cost-effective designs typically require excavations 10-15 m (33-49 ft) deep. In addition, wind energy projects require roads and equipment pads sufficient to get the turbines to the sites and accommodate the cranes required to install the turbines. Soils that are not readily excavated or graded can significantly increase project costs.

An additional consideration when examining site soil conditions is erosion. Controlling erosion will be more difficult for some combinations of soils, weather conditions, and terrain than others.

2.3.8 Exposure to Extreme Wind Speeds (Typhoons) or Other Climatological Events

In the Philippines, the climatological condition of greatest concern is typhoons. While wind turbines are normally designed to withstand the extreme wind speeds associated with typhoons, multiple exposures to these wind speeds are not usually part of the turbine design criteria. Therefore, sites with a relatively low incidence of strong typhoon-induced winds are preferred.

The Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) studied the frequency of typhoons from 1948 to 1998 and ranked all 71 provinces based on storm frequency. The ranking table used in this screening study is included in appendix B.

2.3.9 Density and Frequency of Flying Insects

Insects will affect the leading edge of the wind turbine blades, reducing the performance of the turbines. Insects can be removed from the blades by washing or during rainstorms when the turbines are operating. However, insects will cause a decrease in performance and increase maintenance costs if the blades must be routinely washed.

Often, little is known about the insect population at a wind energy site. Conversations with local residents and biologists familiar with the area can provide useful information concerning such factors as seasonal patterns of insect hatching, type of insect, and density of groupings.

2.3.10 Cultural and Environmental Concerns

Protected or endangered flora and fauna can increase the costs of wind energy project development. Projects usually can be built in a manner that minimizes their effect on these species; however, this takes time and money. All other factors being equal, sites with no endangered or protected species are preferred to sites containing endangered or protected species.

Development of sites that have cultural significance may be offensive to some parties. These concerns can also increase costs or delay a project and should be considered in the site selection process. Examples of cultural significance include burial, religious, historical, or archeological sites.

2.3.11 Aviation/Telecommunications Conflicts

Sites located close to airports or telecommunications facilities must be installed in a manner that accommodates these activities.

2.3.12 Site Capacity

The ability of the site to accommodate the planned project size and potential future expansion must be considered. This is particularly true if a significant investment in transmission system upgrades is required to deliver energy from the project to the site. The site's capacity must be determined using turbines that can be transported to and erected on the site. Typically, more complex terrain will be more optimally developed with relatively smaller turbines because larger cranes and trucks are needed for larger turbines. Capacity is usually affected by the amount of terrain that is relatively high compared to the surrounding area, such as long ridgelines or plateaus. Areas with more isolated hilltops offer less ideal locations for turbines, hence may hold less capacity.

2.4 Step 4 Preliminary Site Ranking

To facilitate the application of the screening criteria described above, a preliminary spreadsheet was developed to assign a relative score to each of the key ranking criteria. Based on information obtained in the Philippines and application of the original ranking process during preparation of this report, the screening criteria and ranking process were revised and are presented in Table 1. This revised process has a stronger emphasis on the wind resource and weights certain issues differently from the original process.

To apply the site-screening process, each criteria is assigned a score based on Table 1. The score assigned to the wind resource potential is weighted (multiplied) by a factor of 4 and added to the remaining scores. This weighting reflects the relative importance of the wind resource in selecting a wind energy site. The cumulative scores for the sites are then compared. Sites that receive high scores have more favorable conditions for development of utility-scale wind projects than sites with lower scores. Note that the maximum possible score for each criterion is not the same. The differences reflect the relative importance of the criteria. For example, wind resources of 400-600 W/m^2 (3 points x 4 = 12 points) will have a more significant affect on a project's economics than a site with many insects (1 point). Clearly, assigning rankings is somewhat subjective and may vary between sites. However, they provide a coarse filter by which sites can be ranked.

Table 1. Site Ranking Criteria

	Points Assigned (Score)					
Criteria	**0**	**1**	**2**	**3**	**4**	**5**
Wind resource density based on NREL atlas (W/m^2)	< 300	-	300-400	400-600	600-800	800-1200
On-site wind measurements to confirm wind resource	None	Local Opinion	< 1 Year		1-2 years	> 2 years
Quality of on-site measured wind speed data	None	Low		Moderate		High
Correlation of on-site wind speed data with wind atlas estimates	None	Low		Moderate		Strong
Quality and availability of correlated long-term data	None	Low		Moderate		High
Proximity to transmission lines		>20 km	10-20 km	5-10 km	1-5 km	< 1 km
Upgrades required to existing transmission lines		Extensive	Moderate		Minor	None
Terrain		Rugged	Complex		Rolling	Flat
Accessibility		Poor	Marginal		Good	Excellent
Security		Poor	Satisfactory	Excellent		
Terrain orientation to prevailing wind		Poor	Marginal		Good	Excellent
Landowner concerns		High		Moderate		Low
Social acceptability		Poor		Satisfactory		Excellent
Land costs		High		Moderate		Low
Vegetation over 10 m		Significant		Scattered		None
Soil conditions		Solid Rock	Fractured Rock		Soil/Rock	All Soil
PAGASA rank in frequency of typhoon passages over province	1 - 11	12 - 23	24 - 35	36 - 47	48 - 59	60 - 71
Other environmental issues (corrosion, humidity)		Extensive	Moderate		Minor	None
Insects		Many	Moderate	Few		
Cultural or environmental concerns		Extensive	Moderate		Minor	None
Site capacity, MW		<25		25-50		> 50
Aviation and telecommunications conflicts		Extensive	Moderate		Minor	None

2.5 Step 5 Quantitative Site Assessment

Application of the preceding process to a series of sites provides a qualitative ranking. To refine the process, it is ultimately necessary to conduct a more detailed economic analysis of prospective projects. The specific approach to this activity will depend somewhat on the objectives. Usually the objective will be to obtain the lowest possible cost of energy. Assuming that mature, commercial wind turbines are used for any project under consideration, the two cost-of-energy-related variables that will be affected by the project site are the initial project cost and the annual energy production. Given the tax and incentive structures currently in place in the Philippines, it can be assumed that changes in the annual revenue from a project will have approximately the same proportional effect on the cost of energy as changes in initial project cost. This relationship can be used to assess how changes in either parameter will affect the relative cost of energy from two sites. The following example illustrates this approach.

> Site A and Site B are identical in all ways except that site A has a 5% higher wind speed than site B and is 20 km (12.5 mi) further from existing transmission lines. A 10-MW wind energy project is being considered for both sites. It is estimated that the cost to build the project at site B is $12 million. Transmission lines cost $50,000 per km (0.6 mi). The cost of the transmission line for site A will therefore add $1 million (8%) to the cost of the project. Due to the nonlinear relationship between wind speed and energy production from a wind power plant, the 5% higher wind speed at site A will result in at least a 10% increase in energy production relative to site B. For the purposes of site screening, site A would be preferred to site B because the increase in project cost due to the transmission line (8%) is a smaller percentage than the increase in energy production from the higher wind speeds (10%).

Analysis similar to the preceding example can be conducted to offset project construction costs against energy production. For the purposes of estimating the increase in energy production, a multiplier of approximately 2 applied to the percentage variance in wind speed is appropriate. For example, a 10% increase in wind speed will usually result in roughly a 20% increase in energy production.

This economic information is useful when screening project sites because it allows changes in factors that affect annual revenue (such as the power purchase contract and the wind resource) to be compared against changes in factors that affect project initial cost (such as transmission upgrades, terrain complexity, and turbine price) without developing comprehensive project financial models and detailed cost estimates. Clearly, more detailed development in assessing a project site produces a higher level of confidence in the assessment, but for the purpose of site screening, a relatively coarse estimate may be all that is required.

3 Philippine Meetings Summary

Before applying the screening process in the field, NPC and USAID helped to arrange a number of meetings for GEC with government agencies, government-owned corporations, private companies active in wind resource assessment and project development, and potential purchasers of wind-generated electricity. These meetings were useful for collecting information necessary to refine the screening criteria, gain insight into the local infrastructure and availability of special construction equipment (cranes), and learn about unique challenges that developers have recently faced.

Meetings were held with the following groups and people:

- U.S. Agency for International Development
    - Carmelito Tatlonghari – Energy Program Manager
    - Jose B. Dulce – Project Development Specialist
    - Rosario R. Calderon – Senior Technical Advisor
- Philippine National Oil Company – Energy Research Department
    - Victorino S. Bala – Manager
    - Donna Gay C. Mabutas – Senior Research Specialist
    - Jocelyn V. Barsana – Research Specialist
- Philippine National Oil Company – Energy Development Corporation
    - Herman Guillen – Engineering Design Manager
    - PNOC – Burgos Wind Power Project Staff Engineers
- Tomen Power LTD
    - Mario Jose C. Baile
- Philippine Department of Energy
- Smith Bell & Company, Inc.
    - Fausto Preysler, Jr. – President
    - Ruth Yu-Owen – Vice President/COO
    - Susan Vega
- Alternative Energy Development, Inc.
    - Laurie B. Navarro – President
- National Power Corporation – Privatization and Restructuring External Office
    - Eduardo Buhain – Division Manager
- National Power Corporation – Luzon Transmission Planning Division
    - Robinson Descanzo, PEE – Manager
- Philippine Rural Electric Cooperatives Association, Inc.
    - Wendell V. Ballesteros – General Manager
- Coordinating Council for Private Sector Participation
    - Sylvia D. Clemente – Deputy Executive Director
    - Aloha T. Samoza – Environment and Power Division
- PA Consulting/Philippine Climate Change Mitigation Program
    - Arelene Donaire-Pamintuan

4 Site Visits and Evaluations

Before GEC's arrival in the Philippines, NPC staff prepared an initial list of eight sites on Luzon for further evaluation as potential wind energy development sites. Previous consultants had identified some sites on the list as areas of interest. Other sites were selected by NPC staff based on their proximity to existing generation and transmission infrastructure and reasonable wind resource potential as identified in NREL's wind atlas. On receiving GEC's original site-screening process, NPC personnel visited certain sites to perform preliminary assessments based on the screening process.

When in Manila, GEC's discussions with NPC and USAID partially reduced this list by removing sites that had obvious disadvantages, such as a high number of resorts/vacation homes (Tagaytay, Bantangas), lack of sufficient space (Bagac and Hermosa, Bataan), and lack of wind resource (Jalajala, Rizal). The remaining sites that were assessed are listed below:

- Samploc, Rizal
- Caliraya, Laguna
- Sual, Pangasinan
- Pantabangan, Nueva Ecija
- Carranglan, Nueva Ecija
- Puncan-Digdig, Nueva Ecija.

The last two sites were not on the original list of eight sites. These two sites are near the southern end of the Cordillera Central Mountains, which is an area identified in the NREL atlas as having an excellent resource. NPC staff had previously inspected the mountain area near Puncan, Nueva Ecija, and thought that it warranted further investigation. Because these areas were relatively close to the Pantabangan area, GEC (along with NPC) decided to rank them higher than other sites being considered.

Figure 1 shows the location of the areas investigated for this report with the corresponding estimated wind resource from the NREL atlas. In the following sections, each site is discussed in further detail. A local wind resource map, topographic map, site-screening score table, and panoramic picture is presented for each evaluation area. Compilation of the screening scores and comparison between sites is presented in section 5.

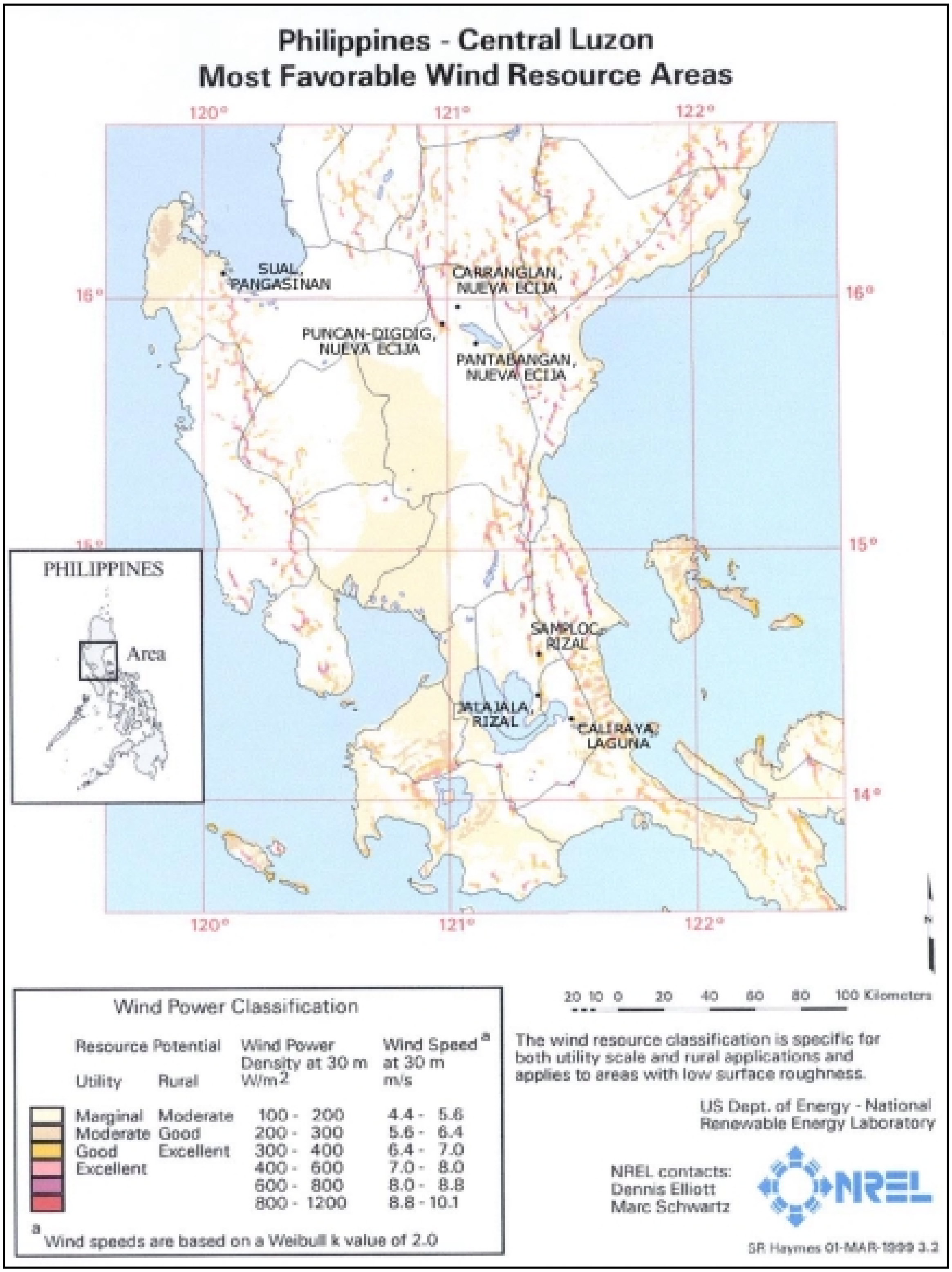

Figure 1. Central Luzon wind resource map

4.1 Samploc, Rizal

Samploc is located approximately 40 km (25 mi) east of Manila in the Province of Rizal. The Tanay PAGASA weather station located north of Samploc was used as the site investigation point. Figure 2 shows a panoramic picture view around the Tanay Station. This station is one of many across Luzon used by PAGASA to acquire weather data. Terrain characterized by GEC as rolling to complex is illustrated in the topographic map in Figure 3.

Figure 4 shows the location of the Tanay station with respect to NREL's wind atlas. The wind resource potential at the site visited was categorized on the NREL wind atlas as moderate; however, the surrounding terrain was categorized as a mix of good to excellent, corresponding to power densities from 300-600 W/m^2. The hills shown in Figure 2 are examples of this terrain.

During the site visit, GEC reviewed the wind speed data and measurement techniques. Table 2 summarizes the average wind speed data collected at the station between December 1999 and August 2000.

Table 2. Tanay PAGASA Station Wind Speed Data [10 m (32.8 ft) height]

Month	Average Wind Speed (m/s)	Maximum Wind Speed (m/s)
December 1999	4	14
January 2000	3.4	15
February 2000	4	12
March 2000	3	15
April 2000	3.2	15
May 2000	3	-
June 2000	2	-
July 2000	4	20
August 2000	3	15

These data are consistent with the NREL wind atlas and indicate a relatively poor wind resource at the PAGASA station. Wind speed data are collected manually once every 3 hours from the 10-m (32.8-ft) meteorological tower shown in appendix C, picture 18. Daily averages are calculated from 8 wind-speed readings collected in a 24-hour period. Wind data have been collected at this station for a number of years (the exact number is not known). Overall the quality of the data is considered to be low given the technique employed, apparent age of measurement equipment, and possible building/vegetation influences around the meteorological tower.

The site received a high score for having measured wind speed data over multiple years; however, the quality and usefulness of the data for estimating the resource with a high degree of confidence was determined to be low. Soil conditions appeared very conducive for construction of foundations and roads. Accessibility of the area was generally viewed as good with the exception of low overhead power/telephone lines and a few sharp corners in the outlying towns around Manila. It was assumed that alternative routes could be found to accommodate the nacelles, blades, and tower equipment. Rizal province is apparently well protected from severe storms and typhoons; it was ranked 50th of 71 provinces in frequency of such storm events.

The area appears to lack a transmission infrastructure adequate to support a 20- to 50-MW wind power plant. The only local transmission lines are 13-kV distribution lines. Higher voltage lines (69 to 230 kV) are located approximately 10 to 20 km (6.2 to 12.4 mi) to the southwest.

Although the undulating terrain does not prevent development of a wind power facility, it influences project size and costs. Low areas and ravines are eliminated from consideration for turbine placement. Turbines can be located in remaining areas provided that prevailing wind directions and wake influences are taken into consideration. These influences tend to further reduce the number of turbines that can be deployed in rolling-to-complex terrain, leading to a reduced site capacity.

Project costs are also influenced by terrain due to increased cut-and-fill excavation work necessary for access roads and crane pad areas around each turbine location. Terrain also influences the rate of turbine construction because crane equipment is typically disassembled to facilitate movement between turbines. Repeated disassembly and reassembly of the crane(s) reduces construction productivity and increases costs.

A detailed breakdown of the site-screening scores is presented in Table 3. Overall assessment of the Samploc site results in the following conclusions:

- Measured wind speed data need to be collected from well-exposed and easily accessed ridges in the areas where the NREL maps indicated the existence of a reasonable wind resource.
- Difficult terrain will increase project costs, but will not prevent construction.
- Transmission access for the site is less than optimal, but may be acceptable.
- The site has potential for development, but the terrain is not optimal.

West Northwest North

Northeast East Southeast

Figure 2. Samploc, Rizal, panoramic view

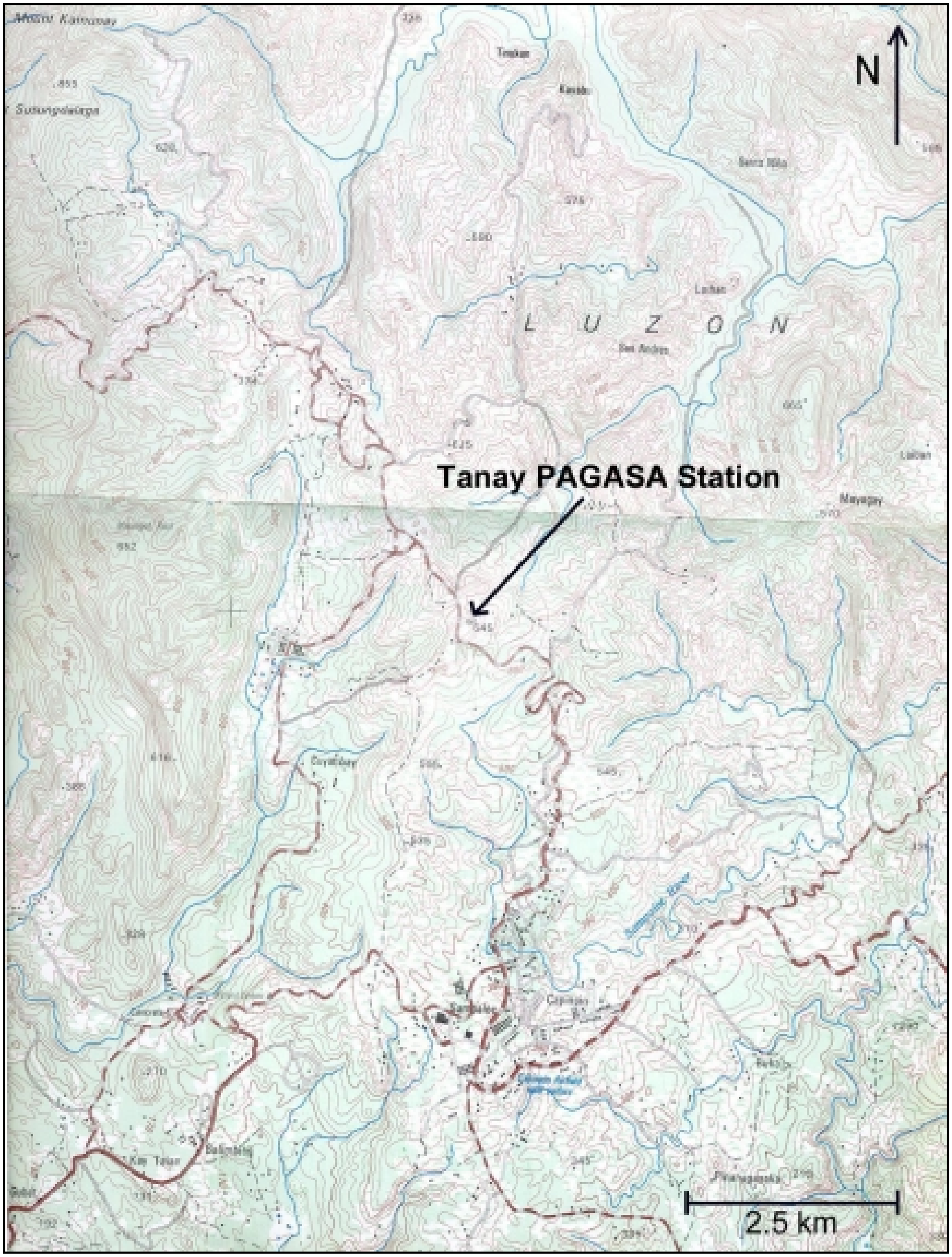

Figure 3. Samploc, Rizal, topographic map

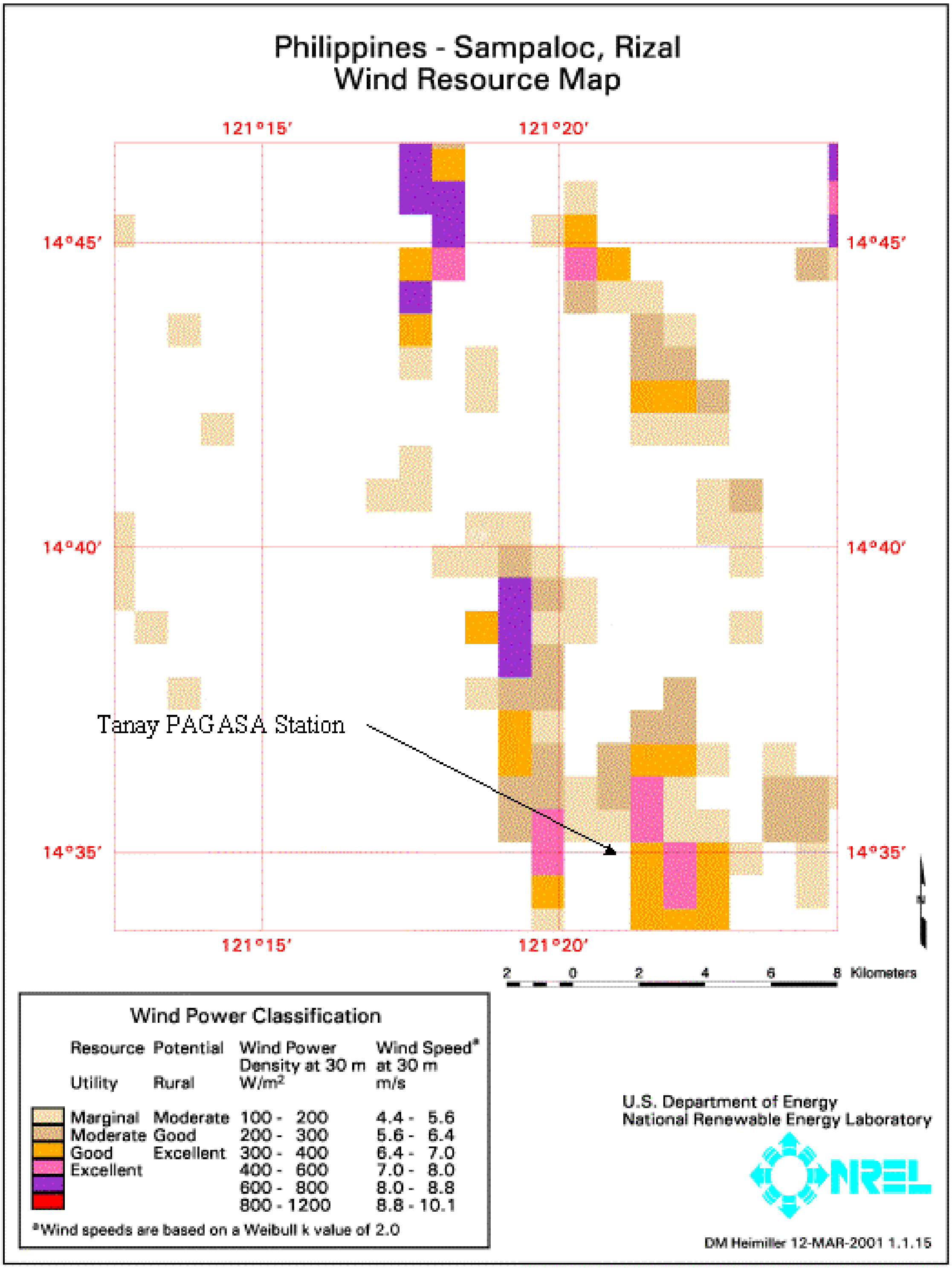

Figure 4. Samploc, Rizal, wind resource map

Site: Samploc, Rizal (Tanay PAGASA Station) Lat/Long: : 14° 34.88', 121° 22.2', elev: 640 m

Prepared by: Kevin Smith, Tim McCoy Date: April 20, 2001

Table 3. Samploc, Rizal, Site-Screening Survey Results

Criteria	Score (5 Excellent – 0 Poor)	Comments
Wind resource density based on NREL atlas	3	Area around PAGASA station was identified as a mix of "Excellent" and "Good" wind resource potential. A few higher elevation areas were estimated at 600-800 W/m^2.
On-site wind measurements to confirm wind resource	0	Although multiple years of records from PAGASA station exist, the measurement location was not in the area of good wind potential.
Quality of on-site measured wind speed data	0	Wind speed data recorded manually every 3 hours. No automated data loggers are used. Daily averages are based on 8 readings over a 24-hour period. Anemometer readings may be influenced by building and vegetation. Anemometer type appears old, may be lower accuracy.
Correlation of on-site wind speed data with wind atlas estimates	0	No on-site wind data exist to evaluate.
Quality and availability of correlated long-term data	1	Presence of PAGASA station provides some low-quality data.
Proximity to transmission lines	2	69-kV to 230-kV lines about 10-20 km away (local lines are 13 kV).
Upgrades required to existing transmission lines	1	No viable local transmission lines. Significant upgrades would be necessary.
Terrain	4	Rolling to moderately complex. Some ridgelines on hilltops. Cut-and-fill work for installation of access roads would be more than typical due to lower turbine density and undulating terrain.
Accessibility	4	Roads from Manila may be difficult to negotiate with turbine components due to a few narrow switchbacks and sharp 90-degree turns in towns with buildings built close to the road. Local access roads are a combination of concrete and dirt. Grading work on local roads will be necessary.
Security	2	Assumed to be satisfactory.
Terrain orientation to prevailing wind	4	Good exposure seemed apparent from NE.
Landowner concerns	3	Assumed to be moderate.
Social acceptability	3	Local villages, a few expensive houses in the area.
Land costs	3	Assumed to be moderate.
Vegetation over 10 m	3	Some trees and bushes but relatively sparse.
Soil conditions	5	All soil.
Typhoon passages over provinces (based on PAGASA rankings)	4	Rizal was ranked 50th by PAGASA.
Other environmental issues (corrosion, humidity)	4	Aside from possible erosion, no other obvious issues were apparent.
Insects	3	Assumed to be few based on previsit discussions with NPC.
Cultural or environmental concerns	4	Assumed to be minor due to low population in area.
Site capacity, MW	3	Combination of rolling terrain and lack of ridgelines would result in a scattered turbine placement layout, reducing the potential installation capacity.
Aviation and telecomm conflicts	5	No apparent conflicts.

4.2 Caliraya, Laguna

Caliraya is located approximately 70 km (43 mi) southeast of Manila in the Province of Laguna. The area around Caliraya is a popular resort destination and consists of hotels and vacation homes. A panoramic picture of the area is shown in Figure 5. Figure 6 presents the topographic map for the area around Caliraya. The area north of the lake contains three ridge-like features oriented perpendicular to the northeast. These areas were the focus of the evaluation because they appeared to have good exposure to prevailing winds from the northeast and southwest.

NPC's Kalayaan pump-storage and Caliraya hydropower generating plants are adjacent to the evaluation area. NPC uses the pump portion of the facility to fill the reservoir during nonpeak periods and operates the generating side to meet peak demand. Wind-generated electricity could work well with this hydropower facility because wind could provide a portion of the power needed to operate the reservoir pumps (when their operation is necessary). During other times, the hydropower plant could provide a means to firm up the output from the wind plant. More detailed load matching and wind resource characterization is necessary to determine if the wind resource, pumping, and generating frequency is compatible.

Figure 7 identifies the location visited by GEC with respect to the estimated wind resource potential from NREL's atlas. Wind resource in the area evaluated on the north side of Caliraya Lake was characterized as marginal to good, corresponding to power densities from 200-400 W/m^2. No on-site or near-site wind speed measurements are known to exist. However, windsurfing on Caliraya Lake is a popular recreation activity, providing some basis of support for the estimated wind resource.

A new development that appeared to include a golf course was under construction on one ridge north of the lake. The close proximity of transmission lines is apparent in Figure 5. The terrain on top of the ridges was characterized as rolling with fewer trees in excess of 10 m (32.8 ft) height than were observed in the valley areas. The installation capacity potential for the three ridges was estimated to be between 25 and 50 MW.

The earthwork is visible to the east in the panoramic view shown in Figure 5. The presence of resorts and vacation homes around the lake were viewed as detriments to development of a wind power project. Landowner concerns, social acceptability, and land acquisition costs were all estimated to be difficult or high. However, if local people view the presence of the turbines as a benefit to their resort/tourist industry, then these concerns may be reduced.

A detailed breakdown of the site-screening scores is presented in Table 4. Overall assessment of the Caliraya site results in the following conclusions:

- Measured wind speed data need to be collected from well-exposed and accessible ridges to improve the understanding of the local wind resource. The NREL atlas may be underestimating the resource potential.
- Landowners need to be contacted to begin assessing the acceptability of wind turbines in this area.
- Load, generating frequency, and pumping analysis should be performed to evaluate the compatibility of the existing hydropower facility with a wind farm.
- The site has potential for development, but wind resource and land costs need to be better defined.

Figure 5. Caliraya, Laguna, panoramic site view

Figure 6. Caliraya, Laguna, topographic map

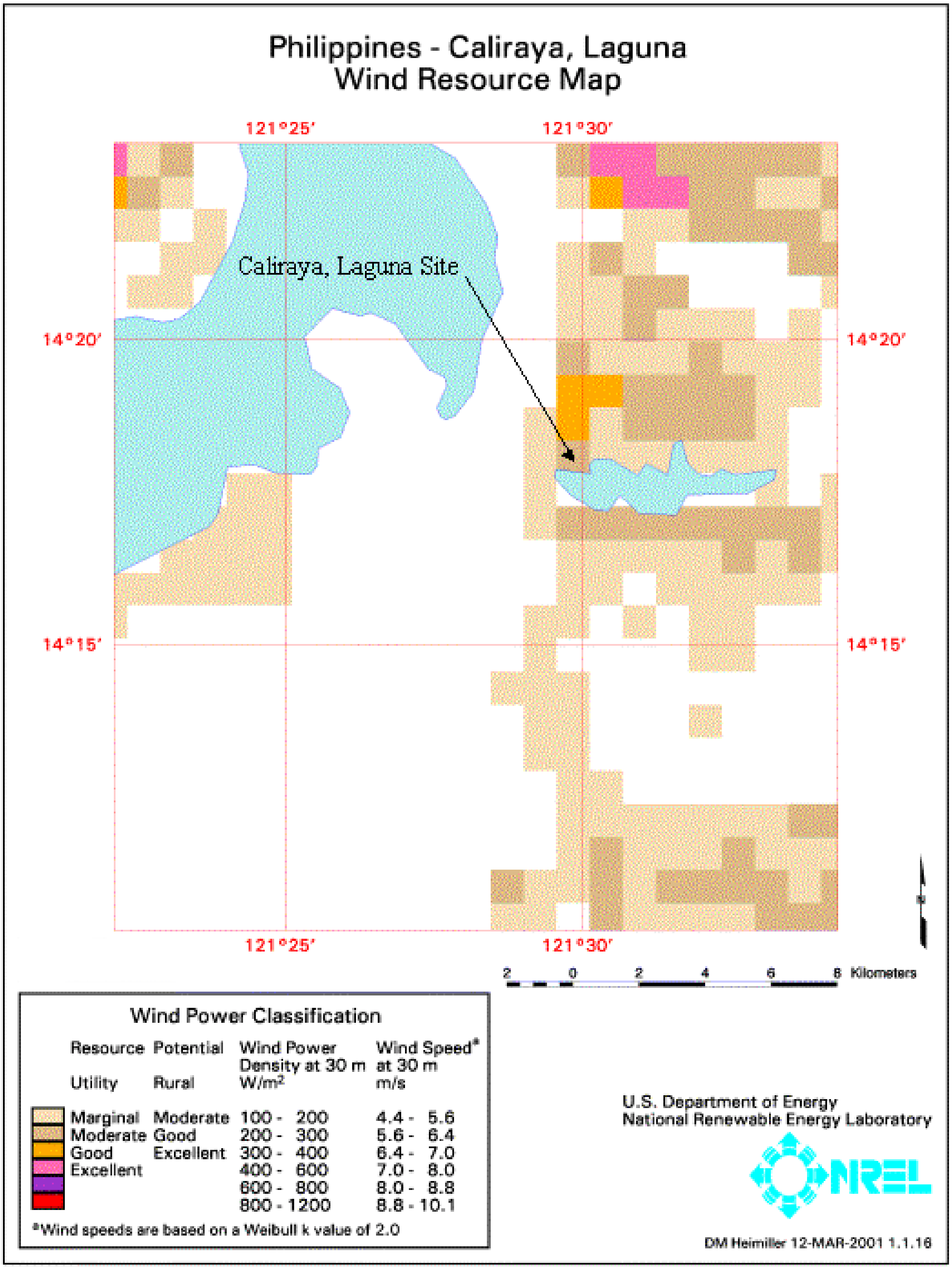

Figure 7. Caliraya, Laguna, wind resource map

Site: Caliraya, Laguna – PNOC Pump/Storage Facility Lat/Long: 14° 17.7' , 121° 29.8', elev: 300 m

Filled out by: Tim McCoy Date: April 20, 2001

Table 4. Caliraya, Laguna, Site-Screening Survey Results

Criteria	Score (5 Excellent – 0 Poor)	Comments
Wind resource density based on NREL atlas	2	Area on north side of reservoir was inspected. NREL wind atlas identified resource potential as "Moderate" to "Good."
On-site wind measurements to confirm wind resource	1	No on-site measurement data exist. Windsurfing on reservoir is a popular activity.
Quality of on-site measured wind speed data	0	No data to evaluate.
Correlation of on-site wind speed data with wind atlas estimates	0	No data to evaluate.
Quality and availability of correlated long-term data	0	Not probable.
Proximity to transmission lines	5	32-MW pump storage facility with 230-kV transmission lines. Transmission lines to the east run along ridge on north side of reservoir; they may pose problems for turbine placement.
Upgrades required to existing transmission lines	5	None anticipated due to proximity of hydro generating source.
Terrain	4	Terrain atop ridges appears rolling. Area between ridges appears more complex.
Accessibility	4	Roads from Manila may be difficult to negotiate with turbine components due to a few narrow switchbacks and sharp 90-degree turns in towns with buildings built close to the road. Once in the flat land near the generating station, the local roads looked good. Access road to the storage reservoir was good due to presence of resorts at the reservoir.
Security	2	Most likely not a problem.
Terrain orientation to prevailing wind	5	Ridgelines are perpendicular to the northeast with decent exposure.
Landowner concerns	1	High. Resorts in area and golf course (under construction) nearby, all at higher elevations where turbines would be located.
Social acceptability	1	Assumed to be poor due to presence of resorts and golf course.
Land costs	1	Assumed to be high due to resort, vacation homes, and possibly more construction in the future.
Vegetation over 10 m	3	Small to medium trees appear more prevalent in valley areas. Ridgelines appear more clear, but not completely free of trees.
Soil conditions	5	Dirt. Local excavation project (for golf course) had extensive excavation work visible. Excavation cross-sections revealed all soil to depths of about 10-15 m. No rock or cobbles seen.
Typhoon passages over provinces (based on PAGASA rankings)	4	Laguna was ranked 48th by PAGASA.
Other environmental issues (corrosion, humidity)	4	Aside from possible erosion, no other obvious issues were apparent.
Insects	3	Assumed to be few based on previsit discussions with NPC.
Cultural or environmental concerns	2	Resort and vacation homes could increase the difficulty in siting wind projects.
Site capacity, MW	3	Estimated capacity of 3 ridges north of reservoir is 25-50 MW.
Aviation and telecomm conflicts	5	No apparent conflicts. More difficulties exist with transmission lines and towers.

4.3 Sual, Pangasinan

Sual is located approximately 190 km (118 mi) northwest of Manila in the Province of Pangasinan. A 1,218-MW, coal-fired power plant was activated near Sual in 1999. The plant is owned and operated by Southern Company, an independent power producer that sells the energy to NPC through a 25-year agreement. The area southwest of the plant was visited by GEC to gain an understanding of this region. GEC also visited the NPC substation near Labrador southeast of Sual. Figure 8 provides a panoramic view of the area around the coal plant. Mountains to the south, where the wind resource potential is high, can be seen in the background of this picture. Access to these mountains was not attempted due to limited roads and time constraints.

Figure 9 shows the topographic map for the area around Sual and identifies the location of the coal plant and GEC's evaluation area. The transmission substation is located in Labrador, which is at the base of the mountains.

Figure 10 identifies the location of the coal plant with respect to the estimated wind resource potential from the NREL atlas. The actual area visited is slightly off the map; however, the wind resource for the mountainous area is clearly visible in the center of this figure.

The wind resource in the visited area based on Figure 1 was estimated to be marginal. On-site wind speed data from the coal plant obtained by NPC is shown in Table 5.

Table 5. On-Site Wind Speed Data from Sual Coal Plant

MONTH	TEMPERATURE, C		WIND SPEED, m/s		DOMINANT DIRECTION
	MEAN	HIGH	AVERAGE	HIGH	
January	25.3	26.2	0.5	12.5	E
February	27.8	29.3	3.2	16.5	WSW
March	28.2	29.4	2.4	15.6	WSW
April	29.3	30.5	1.2	14.8	WSW
May	28.1	30.8	3.1	18.8	WW
June	28.6	30.4	2.9	18.8	WSW
July	26.2	28.5	3.8	24.6	WSW
August	27.7	29.3	1.2	13.9	NNW
September	27.1	29.5	2.6	18.3	WSW
October	28	28	0.1	7.2	S
November					
December	27.4	28.8	1.2	18.3	ENE
	27.61	**29.15**	**2.02**	**16.30**	**WSW**

The measurement height for the data is not known and NPC believes the data-logging equipment may have experienced some operating problems resulting in missing data. Although not definitive, the data appear to support the “marginal” resource assessment. From the inspection location, areas to the south, which were characterized as good to excellent in Figure 10, could be seen. There are no known measured wind speed data for the mountain areas.

The Sual area received high scores for proximity to transmission, very good access from the water and land, rolling terrain, low vegetation, and accommodating soil conditions. In addition, issues related to landowner concerns and land costs were not viewed to be as challenging as for Caliraya.

A detailed breakdown of the site-screening scores is presented in Table 6. These scores are based on the wind and land assessment for the areas south of the Sual coal plant and west of the Laborador substation. Overall assessment of the Sual area results in the following conclusions:

- More detailed evaluation of the mountain areas should be performed and contacts with landowners made.
- Measured wind speed data need to be collected from well-exposed and accessible locations where the NREL maps indicate existence of good to excellent wind resources.
- The area has potential for development.

Northeast East Southeast South Southwest

West Northwest North

Figure 8. Sual, Pangasinan, panoramic site view

Figure 9. Sual, Pangasinan, topographic map

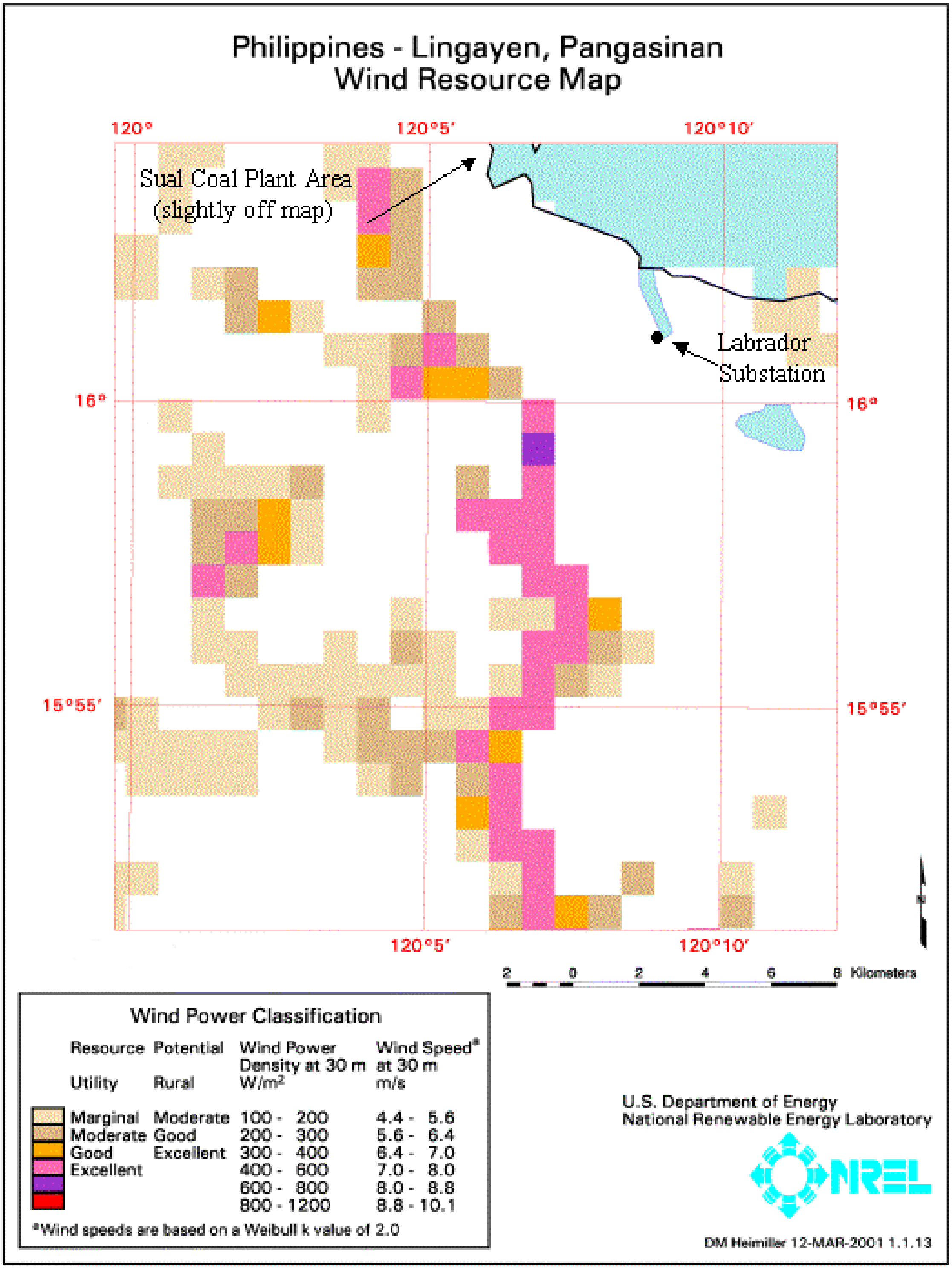

Figure 10. Sual, Pangasinan, wind resource map

Site: Sual, Pangasinan – 1218 MW Coal Plant

Lat/Long: 16° 4.6', 120° 7.6' , elev: 170 m

Filled out by: Tim McCoy, Kevin Smith

Date: April 21, 2001

Table 6. Sual, Pangasinan, Site-Screening Survey Results

Criteria	Score (5 Excellent – 0 Poor)	Comments
Wind resource density based on NREL atlas	3	Mountain area south of inspection area is basis for resource score. NREL wind atlas identified area to the south as excellent.
On-site wind measurements to confirm wind resource	0	No on-site measurement data are available.
Quality of on-site measured wind speed data	0	No data to evaluate.
Correlation of on-site wind speed data with wind atlas estimates	0	No data to evaluate.
Quality and availability of correlated long-term data	0	On-site measurements at the coal plant for a partial year showed a resource with an average speed of 2 m/s with the average maximum value of 16 m/s.
Proximity to transmission lines	4	Coal plant within 5 km is connected with 230-kV lines. Interconnect at the Laborador substation for a wind plant may be an option.
Upgrades required to existing transmission lines	5	None expected. Local grid is expected to be very strong due to presence of coal plant.
Terrain	4	Rolling hills in vicinity of inspection area. Slightly more mountainous area present where NREL wind atlas identified better resource potential.
Accessibility	4	Port at coal plant, good roads in area. Nearby mountains will be more difficult to access.
Security	2	Based on NPC information, area was historically identified as having some military activity. Presence of power plant has significantly reduced these activities.
Terrain orientation to prevailing wind	4	No obvious ridgelines in inspection area. Mountains to the south have some orientation perpendicular to NE winds.
Landowner concerns	3	Mix of government/privately owned land. Coal plant may improve image of wind project.
Social acceptability	3	Locals recognized value of coal power plant for jobs; same feeling may exist with wind energy projects.
Land costs	3	Unknown but assumed to be moderate.
Vegetation over 10 m	3	Sparse low bushes and trees were noted on hilltops at inspection area; all appeared less than 10 m. More trees in excess of 10 m are highly likely in mountainous area to the south.
Soil conditions	5	Mostly dirt. Appears erosion prone.
Typhoon passages over provinces (based on PAGASA rankings)	2	Pangasinan was ranked 24th by PAGASA.
Other environmental issues (corrosion, humidity)	4	Aside from possible erosion, no other obvious issues were apparent.
Insects	3	Assumed to be few based on previsit discussions with NPC.
Cultural or environmental concerns	4	Hundred Islands National Park is located in area north to northwest from Sual.
Site capacity, MW	5	Local area inspected was estimated to accommodate between 25 and 50 MW. More capacity appeared possible in mountains to the south.
Aviation and telecomm conflicts	5	No apparent conflicts.

4.4 Pantabangan, Nueva Ecija

Pantabangan is located approximately 130 km (80 mi) north of Manila in the province of Nueva Ecija. It is one of three areas in the province that were evaluated in this study. The other two are Puncan-Digdig and Carranglan. NPC owns and operates the 100-MW hydropower plant near Pantabangan, which helped facilitate access to this area. Figure 11 shows some views of the reservoir and surrounding area near the hydro facility. Figure 12 presents the topographic map for the areas evaluated in Nueva Ecija.

Figure 13 locates the hydropower plant and areas visited with respect to NREL's wind map. The area near the hydropower plant has no wind resource potential identified on the NREL atlas. The area was evaluated; however, because NPC could obtain access to this area and it was close to the southern end of the Cordillera Central Mountains where more suitable wind resources are shown in the NREL atlas. This area is discussed in the Carranglan section of this report (Section 4.6).

Despite the lack of wind resource potential, the screening criteria were applied to the Pantabangan area. The area received high score for good access to transmission lines, good access roads, and accommodating soil conditions. Low scores were assigned for complex terrain, significant vegetation over 10 m (32.8 ft) in height, typhoon frequency, and low potential installation capacity.

A detailed breakdown of the site-screening scores is presented in Table 7. The conclusion of the assessment is that no further evaluation of the Pantabangan area is warranted because the wind resource is insufficient to make development of a wind facility likely.

Northwest North Northeast

South

Figure 11. Pantabangan, Nueva Ecija, panoramic views

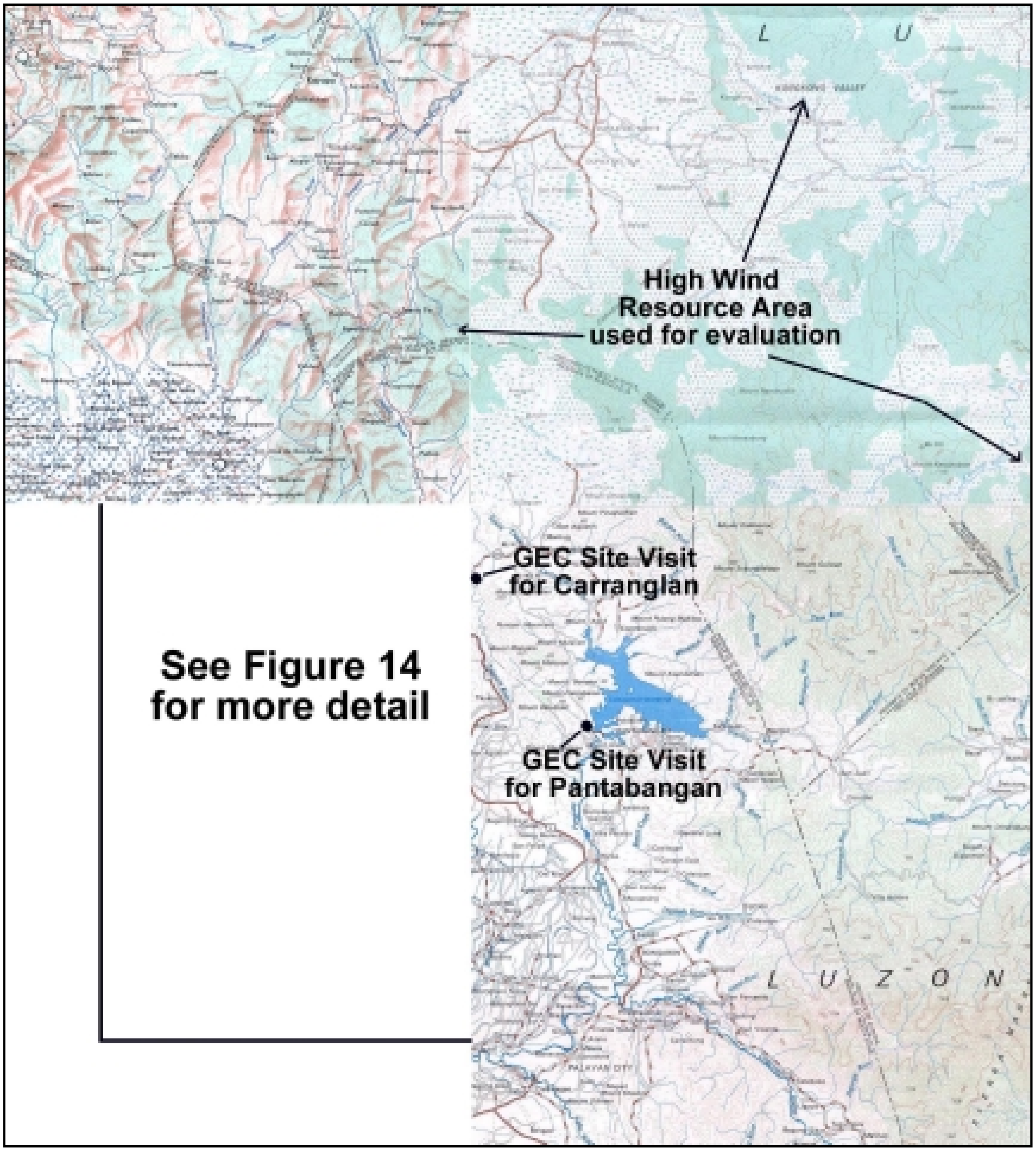

Figure 12. Pantabangan and Carranglan, Nueva Ecija, topographic maps

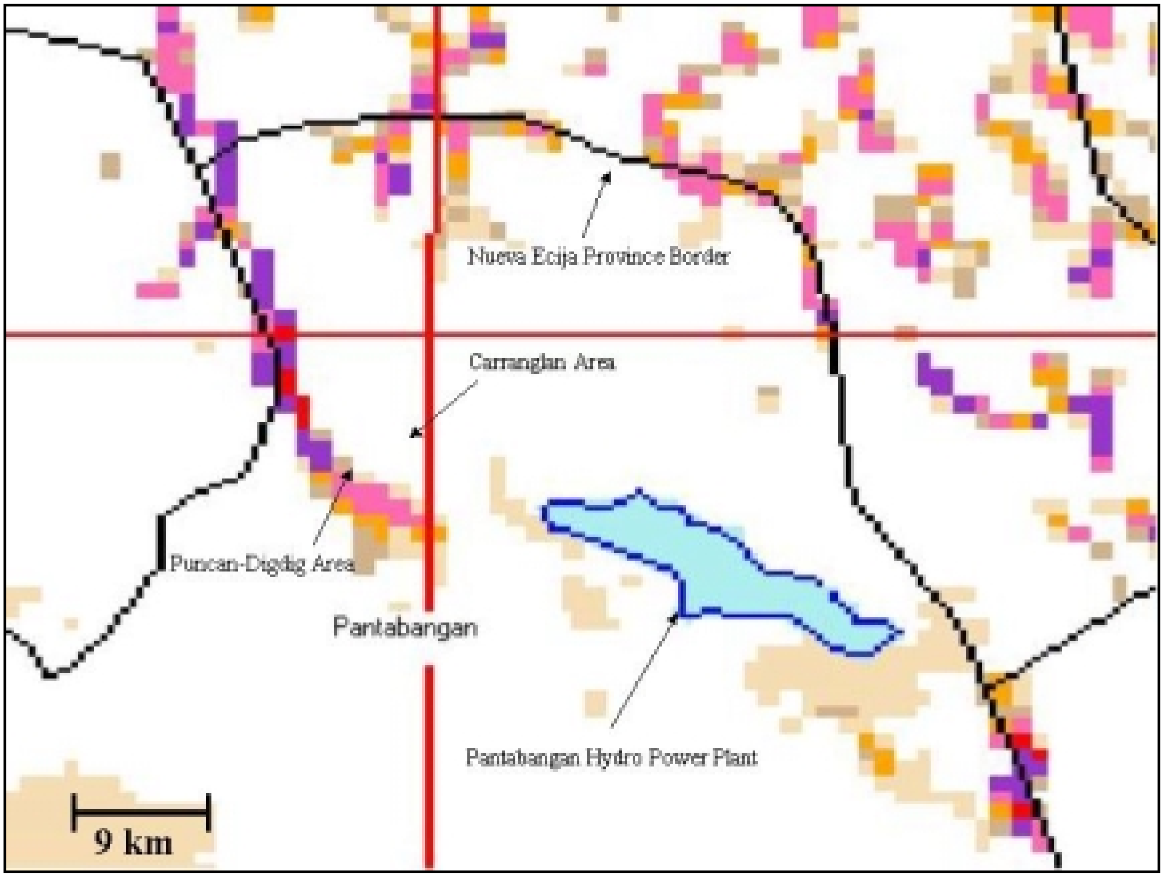

Figure 13. Pantabangan, Nueva Ecija, wind resource map

Site: Pantabangan, Nueva Ecija (hydro plant) Lat/Long/Elev: 290 m

Filled out by: Kevin Smith Date: April 22, 2001

Table 7. Pantabangan, Nueva Ecija, Site-Screening Survey Results

Criteria	Score (5 Excellent – 0 Poor)	Comments
Wind resource density based on NREL atlas	0	Earthen dam area visited – no developable resource identified on wind atlas. However, atlas identified area southeast of reservoir as having a "Marginal" resource (100-200 W/m^2).
On-site wind measurements to confirm wind resource	0	None found at time of visit, unlikely at hydro facility. Area southeast of reservoir may be worth investigating.
Quality of on-site measured wind speed data	0	No data to evaluate.
Correlation of on-site wind speed data with wind atlas estimates	0	No data to evaluate.
Quality and availability of correlated long-term data	0	None.
Proximity to transmission lines	4	Hydro facility (250 MW) located within 5 km.
Upgrades required to existing transmission lines	4	Minor due to existing hydro plant. Need to evaluate excess capacity between hydro and main line.
Terrain	2	Moderately complex, may be difficult to build large capacity (i.e., 20- to 40-MW) facility.
Accessibility	5	Good roads to hydro plant.
Security	3	Good security due to existing hydro plant.
Terrain orientation to prevailing wind	2	No ridgelines. High spots are oriented in ring around reservoir. Blocking mountains were noted to northeast.
Landowner concerns	3	Small local resort on one of the hilltops, but most land is government-owned near hydro plant.
Social acceptability	3	Resort area.
Land costs	3	Government land may be available at moderate costs.
Vegetation over 10 m	1	Many trees observed, although some hilltops clear.
Soil conditions	5	Primarily dirt, very little rock.
Typhoon passages over provinces (based on PAGASA rankings)	1	Nueva Ecija was ranked 23rd by PAGASA.
Other environmental issues (corrosion, humidity)	4	Erosion due to loose soil and likely vegetation removal.
Insects	3	Assumed to be few based on previsit discussions with NPC.
Cultural or environmental concerns	4	Resort
Site capacity, MW	1	10 MW in reasonably close proximity.
Aviation and telecomm conflicts	5	Lots of cellular, but little else.

4.5 Puncan-Digdig, Nueva Ecija

This area is the second evaluated by GEC in the province of Nueva Ecija. Puncan and Digdig are two villages located approximately 150 km (93 mi) north of Manila. The villages are at the base of the Cordillera Central Mountains along Highway 5 between San Jose and Bayombong.

The southern end of the Cordillera Central Mountains, directly west from these villages, is the focus of GEC's evaluation in this area. NPC personnel previously hiked to the top of these mountains from the Puncan area; however, GEC's review was conducted from the mountain base due to time constraints.

Figure 14 presents the topographic map for the area near Puncan and Digdig. The mountains possessed very steep sides and attain typical elevations of approximately 800 to 1,200 m (2,600 to 3,900 ft). No access roads to the mountain top areas are noticeable in Figure 14.

Figure 15 identifies the location of GEC's visit with respect to NREL's estimated wind resource potential map. NREL's wind atlas identified these mountains as having greater than excellent wind resource potential, with estimated power density reaching 1,200 W/m^2. No on-site or near-site measured wind speed data are known to exist for the mountaintop areas.

The mountain area received high scores for wind resource, orientation to prevailing wind direction, soil conditions (based on general observations of conditions from previous areas in the Philippines), and site capacity. Accessing the mountaintop areas; however, resulted in a number of low scores. Access to the base of the mountain was good and was not viewed as posing any difficulties. Accessing the mountaintop through the complex terrain would result in construction of long and costly roads with significant cut-and-fill work necessary. The mountains were covered in trees estimated to be greater than 10 m (32.8 ft) in height, which would need to be removed for the roads and thinned near the turbines. Tree removal and road construction was assumed to have an adverse effect on the social acceptability of a wind power project in this area.

Access to transmission lines in the valley from the mountaintop locations was estimated to require the construction of approximately 10 to 20 km (6.2 to 12.4 mi) of new transmission lines.

None of these concerns would completely eliminate this area from consideration for placement of a wind power project because the wind potential appears very high. However, there may be other areas that are easier to access and require fewer improvements. A comparison of this area to wind power projects in the Tehachapi Pass area of California showed that the Puncan-Digdig area had greater slopes, more undulating terrain, significantly more vegetation, and no existing access roads where turbine placement would be considered. In contrast, the complex area of Tehachapi Pass had preexisting roads (due to ranching), lacked vegetation, and had moderately flat to rolling areas on top of ridges where a large number of wind turbines could be placed.

A detailed breakdown of the site-screening scores is presented in Table 8. Overall assessment of the Puncan-Digdig area results in the following conclusions:

- Although the wind resource appears to be the best of all sites evaluated for this report, the mountaintop location, very complex local terrain, and heavy forest growth place many limits on potential development.
- If communication towers exist on the mountaintop, then wind measurement equipment could be installed to verify wind atlas estimates.
- Since development potential appears low for reasons other than the wind resource, placement of a meteorological tower and measurement equipment at this site is not recommended unless investigation of other, more accessible sites indicates that they do not have sufficient wind resources to support development.

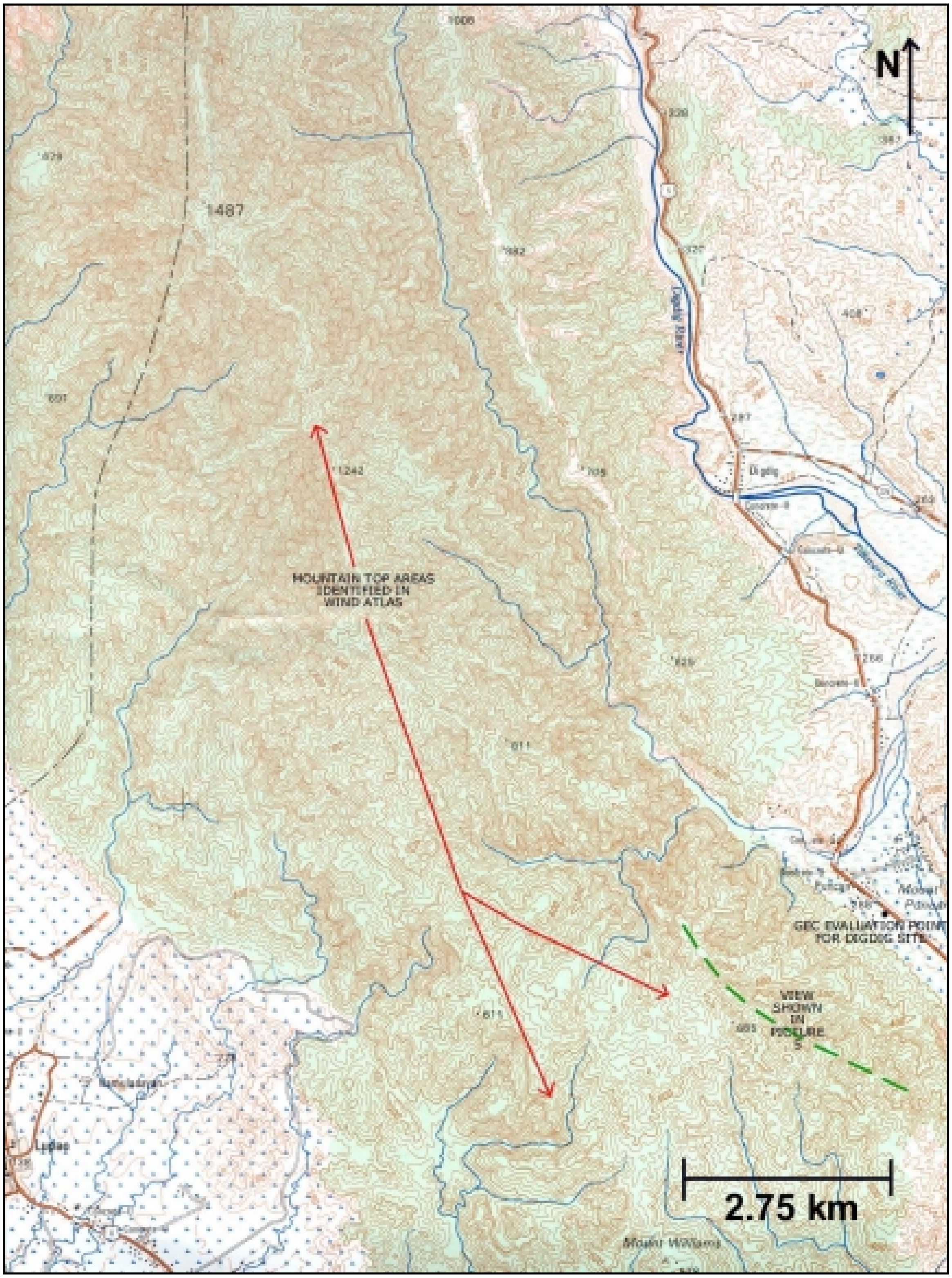

Figure 14. Puncan-Digdig, Nueva Ecija, topographic map

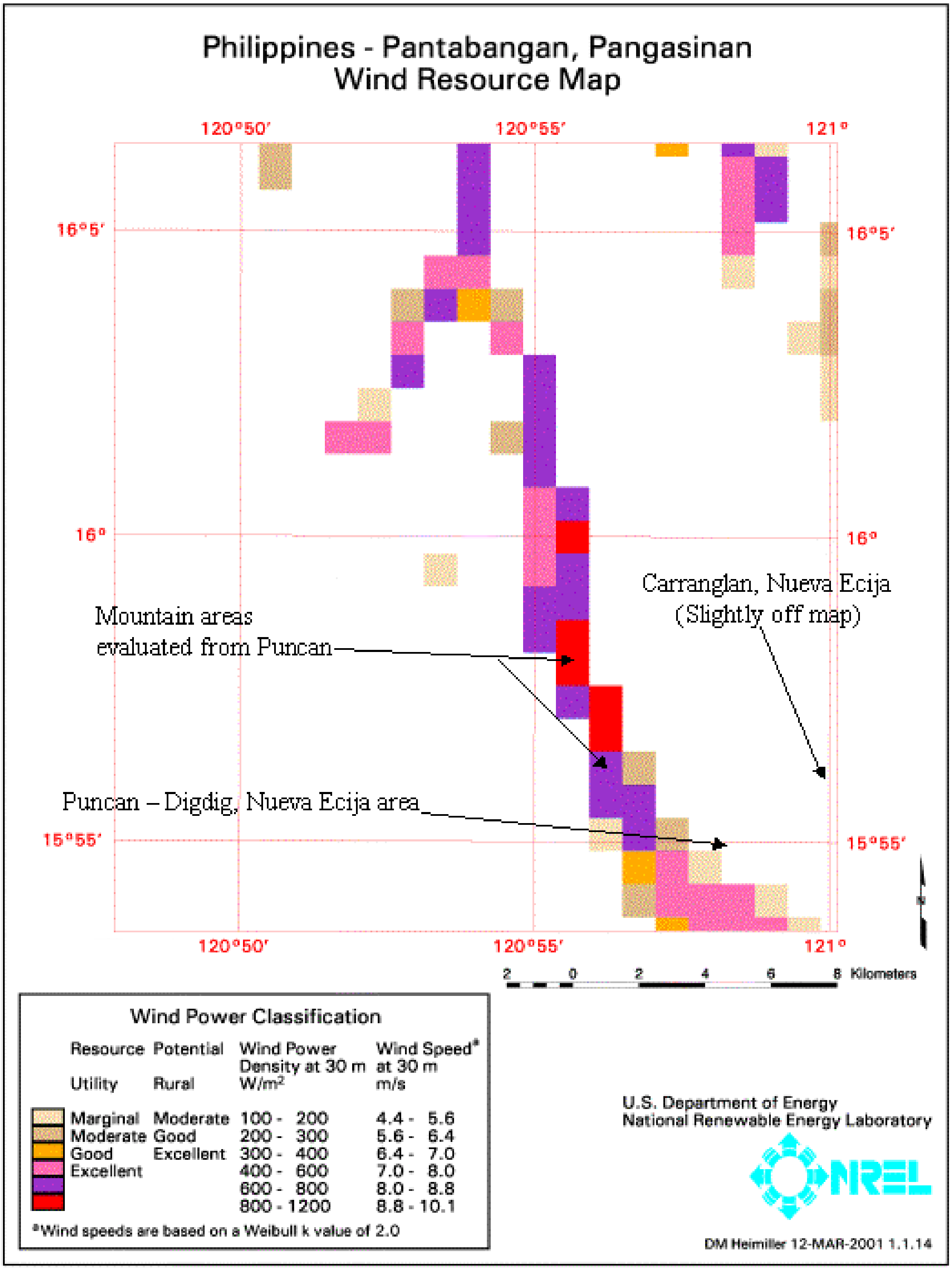

Figure 15. Puncan-Digdig and Carranglan, Nueva Ecija, wind resource map

Site: Puncan, Digdig, Nueva Ecija – MOUNTAIN LOCATION Lat/Long/Elev: 275 m

Filled out by: Tim McCoy Date: April 22, 2001

Table 8. Puncan-Digdig, Nueva Ecija, Site-Screening Survey

Criteria	Score (5 Excellent – 0 Poor)	Comments
Wind resource density based on NREL atlas	5	Assessment area was in vicinity of Puncan and Digdig, where mountains are adjacent to Highway 5 (to the west). Mountaintop features were identified on wind atlas as having better than "Excellent" wind resource. Valley is oriented from northeast to southwest along the prevailing wind directions.
On-site wind measurements to confirm wind resource	1	No local wind measurements exist. Locals claim a lot of wind comes from NE in the winter months.
Quality of on-site measured wind speed data	0	No data to evaluate.
Correlation of on-site wind speed data with wind atlas estimates	0	No data to evaluate.
Quality and availability of correlated long-term data	0	Not probable.
Proximity to transmission lines	2	Transmission line runs near highway through valley to the northeast. New transmission lines will be needed to access mountaintop areas.
Upgrades required to existing transmission lines	4	Unlikely; however, dependent on available capacity of existing lines.
Terrain	2	Challenging but not impossible. Once on top of mountain - terrain appears complex based on topographic maps. Heavily wooded.
Accessibility	1	Good roads present in valley provide access to base of mountains. New roads to mountaintops would need to be constructed up some very steep terrain.
Security	3	Mountaintop locations should provide good security because access can be limited.
Terrain orientation to prevailing wind	5	Mountaintops are oriented perpendicular to wind from the NE.
Landowner concerns	3	Unknown. Assumed to be moderate.
Social acceptability	3	Assumed to be satisfactory. Removal of trees and road construction may make social acceptability more difficult.
Land costs	3	Unknown. Assumed to be moderate.
Vegetation over 10 m	1	Significant tree coverage; however, sporadic mountaintop areas may not have tree coverage.
Soil conditions	5	Could not be determined from highway. Based on other areas visited, it is assumed to be similar.
Typhoon passages over provinces (based on PAGASA rankings)	1	Nueva Ecija was ranked 23rd by PAGASA. Well inland, with mountains in the distance offering protection from main track.
Other environmental issues (corrosion, humidity)	4	Erosion a potential problem.
Insects	3	Assumed to be few based on previsit discussions with NPC.
Cultural or environmental concerns	2	Cultural concerns assumed to be low due to low population. Environmental concerns moderate due to tree removal and roadwork requirements.
Site capacity, MW	5	Given enough roadwork and tree removal, more than 50 MW of capacity could be installed.
Aviation and telecomm conflicts	5	None apparent.

4.6 Carranglan, Nueva Ecija

Carranglan is located only 10 km (6.2 mi) east of Puncan and Digdig in the province of Nueva Ecija. The area near Carranglan was evaluated because access for wind turbines appeared considerably easier than for turbines placed on top of the mountains near the Puncan-Digdig area. Carranglan is located in the valley that is formed by the Cordillera Central Mountains. Because of time and security constraints, travel to areas further north of Carranglan, where the NREL atlas identifies good wind resource areas, was not possible. However, GEC considered it important to obtain a land assessment for a typical area in this valley so that it could be applied to other areas in the valley where high wind resources were estimated. Figure 16 presents pictures of the valley area near Carranglan. Vegetation is relatively low and the flat-to-rolling terrain is evident.

The location visited by GEC near Carranglan is shown on the topographic map in Figure 12. Figure 12 also identifies the areas north of Carranglan where developable wind resources were estimated in NREL's wind atlas. The border between the Nueva Ecija and Nueva Vizcaya provinces accurately locates the areas of interest. A few features of this area visible in Figure 12 include low mountains that rise approximately 500 m (1,640 ft) above the valley, rolling terrain around the mountains with some flat areas on the mountain tops, a number of roads extending from the valley to the base of the mountains, and agricultural/plantation land use.

As shown in Figure 13, the NREL atlas identified the area along the Nueva Ecija border as possessing excellent wind energy potential. People interviewed stated that strong winds occur in the valley during the dry season. No measured wind speed data are known to exist for the Carranglan area or the area along the provincial borders.

The long ridge-like features where the high wind resource was identified are perpendicular to the valley. The valley area contains farms and villages and offers a high degree of accessibility. Transmission lines through the valley are evident, offering easier grid access than the Puncan-Digdig mountain area. The agricultural land uses appear to be compatible with deployment of wind turbines. The turbines could even offer an additional source of income for the landowners.

Aside from a higher frequency of typhoons, the valley area did not receive many low scores. The Carranglan area would obviously not be recommended for further investigation because of the lack of a wind resource. Other areas in the valley, where a good to excellent wind resource is predicted by the NREL wind atlas, may be easier to develop than the surrounding mountaintop locations.

A detailed breakdown of the site-screening scores is presented in Table 9. Overall assessment of the Carranglan and Nueva Ecija border area results in the following conclusions:

- Strong development opportunities appear to exist in the area along the Nueva Ecija-Nueva Vizcaya border because of the combination of good wind resources, reasonable access, moderate terrain, and the presence of transmission lines.
- More detailed inspection of the good wind resource areas in Nueva Vizcaya needs to be performed and specific areas for placement of measurement equipment identified.

- Existing communication and cellular phone towers should be located and used as platforms for acquiring wind speed data.
- Where no communication towers exist, meteorological tower equipment should be installed in well-exposed and easily accessed areas.
- Initial contact with landowners to assess the acceptability of wind turbines in the area should be performed.

Southwest Northeast

(with Puncan-Digdig mountain in far background)

Figure 16. Carranglan, Nueva Ecija, views

Site: Carranglan. Nueva Ecija – VALLEY LOCATION   Lat/Long/Elev: 15° 57.1’ 121° 0.6’ 275 m

Filled out by: Tim McCoy, Kevin Smith   Date: April 22, 2001

Table 9. Carranglan, Nueva Ecija, Site-Screening Survey Results

Criteria	**Score (5 Excellent – 0 Poor)**	**Comments**
Wind resource density based on NREL atlas	3	Area along the Nueva Ecija border is the basis of the wind resource score. Valley is oriented from northeast to southwest along the prevailing wind directions.
On-site wind measurements to confirm wind resource	1	No local wind measurements exist. Locals claim there is a lot of wind from NE in the winter months.
Quality of on-site measured wind speed data	0	No data to evaluate.
Correlation of on-site wind speed data with wind atlas estimates	0	No data to evaluate.
Quality and availability of correlated long-term data	0	Not probable.
Proximity to transmission lines	4	Transmission line runs along highway through valley to the northeast.
Upgrades required to existing transmission lines	4	Unlikely; however, dependent on available capacity of existing lines.
Terrain	4	High wind resource region is mountainous; however, terrain did not appear as complex as the Puncan-Digdig area on topographic maps.
Accessibility	5	Good roads present in the valley due to agricultural activity provide access to the mountains.
Security	2	Assumed to be satisfactory.
Terrain orientation to prevailing wind	5	High points appeared to be oriented perpendicular to valley features. Most look good for turbine layout.
Landowner concerns	3	Mostly private land. Agriculture and plantation land uses indicated on maps. Owners may be willing to lease land.
Social acceptability	3	Assumed to be satisfactory.
Land costs	3	Assumed to be moderate.
Vegetation over 10 m	3	Scattered trees. Certain hilltops appeared clear of trees.
Soil conditions	5	All soil.
Typhoon passages over provinces (based on PAGASA rankings)	1	Nueva Ecija was ranked 23rd by PAGASA.
Other environmental issues (corrosion, humidity)	4	Erosion a potential problem.
Insects	3	Assumed to be few based on previsit discussions with NPC.
Cultural or environmental concerns	4	Assumed to be minor due to sparse population in area.
Site capacity, MW	5	Based on apparent space in valley and lengthy perpendicular features, more than 50 MW of capacity could be installed.
Aviation and telecomm conflicts	5	Cellular phone communication towers, little else.

5 Summary Analysis

Table 10 shows site-screening scores from each of the six sites evaluated. Weighting of the estimated wind resource score is shown along with the total overall score for each site. The valley areas north of Carranglan received the highest score, followed closely by the Sual area. Although these areas did not receive the highest wind resource scores, their site-related scores were the highest compiled.

The next highest ranked sites were the mountaintop area near Puncan-Digdig and the Samploc site. The Puncan-Digdig area received the highest wind-resource-related score; however, it received the lowest site-related score because of the difficult mountaintop location. The area around Samploc received reasonable scores for both wind resource and site-related criteria.

Caliraya trailed the Samploc site only in wind resource potential. Although the Caliraya area was perceived to have difficult landowner concerns and high land costs because of the surrounding resort/vacation land uses, the presence of the hydropower facility and good access to transmission helped balance the scoring. If the wind resource is found to be better than estimated, and the perceived land-use issues are not realized, then the Caliraya site would offer a very good development opportunity comparable to the Carranglan and Sual areas.

Application of the screening criteria has resulted in a fair assessment and appropriate ranking of the sites visited by GEC. The final screening criteria offers a good tool for identifying the critical issues related to assessing a site's development potential and provides a method for comparative analysis.

The four sites that should be focused on for further wind resource measurement are the areas north of Carranglan (along the Nueva Ecija border), the mountains south of Sual, Samploc, and Caliraya. The difficult access issues associated with the Puncan-Digdig area relegates wind resource measurement on the mountaintop to a lower priority because development in this area is not likely in the foreseeable future. The other four areas offer much more development potential, thus necessitating wind resource measurement.

Because meteorological towers represent a large cost component for site-specific resource measurement, existing communication towers should be identified as sites for mounting wind sensor equipment and booms. If communication towers are used, it is critical that (1) the towers are located close to an area where turbine placement can be performed, (2) that they are located in well-exposed positions, and (3) that the sensors are mounted on booms so that the wind flow around the tower does not affect the measurements. Where communication towers are not available or not ideally situated, 40- to 50-m (131- to 164-ft) meteorological towers with wind speed and direction sensors at multiple heights should be deployed. Initiating on-site data collection is the highest priority for the four developable areas identified in this report. GEC recommends acquisition of wind data from multiple towers around each of the four areas, not just one tower per area.

In addition, a disciplined review of the NREL wind atlas, the Philippines highway and transmission system, and the site-evaluation methodology developed herein should be applied to other areas of the Philippines to identify additional areas with wind energy development potential.

Table 10. Cumulative Site-Evaluation Scores

	Pantabangan	Carranglan (Valley)	Digdig (Mountain)	Sual	Caliraya	Samploc
Wind resource density based on NREL map	0	3	5	3	2	3
Weighted Score (multiplier = 4)	**0**	**12**	**20**	**12**	**8**	**12**
Duration of on-site wind measurements to confirm wind resource	0	1	1	0	1	0
Quality of on-site measured wind speed data	0	0	0	0	0	0
Correlation of on-site wind speed data with wind atlas estimates	0	0	0	0	0	0
Quality and availability of correlated long-term data	0	0	0	0	0	1
Wind Resource Subtotal	**0**	**13**	**21**	**12**	**9**	**13**
Proximity to transmission lines	4	4	2	4	5	2
Upgrades required to existing transmission lines	4	4	4	5	5	1
Terrain	2	4	2	4	4	4
Accessibility	5	5	1	4	4	4
Security	3	2	3	2	2	2
Terrain orientation to prevailing wind	2	5	5	4	5	4
Landowner concerns	3	3	3	3	1	3
Social acceptability	3	3	3	3	1	3
Land costs	3	3	3	3	1	3
Vegetation over 10 m	1	3	1	3	3	3
Soil conditions	5	5	5	5	5	5
Rank in frequency of typhoon cyclone passage over provinces	1	1	1	2	4	4
Other environmental issues (corrosion, humidity)	4	4	4	4	4	4
Insects	3	3	3	3	3	3
Cultural or environment concerns	4	4	2	4	2	4
Site capacity, MW	1	5	5	5	3	3
Aviation and telecomm conflicts	5	5	5	5	5	5
Site Related Subtotal	**53**	**63**	**52**	**63**	**57**	**57**
TOTAL SCORE	**53**	**76**	**73**	**75**	**66**	**70**

Appendix A

TO: Yih-Huei Wan, NREL

FROM: Kevin Rackstraw

RE: Philippines Wind Policy Update

DATE: March 8, 2001

CC: Robert Poore, GEC

Several changes have been made over the last year to the regulations governing the treatment of wind energy in the Philippines. These changes improve the environment for wind projects, although there are several areas of concern that remain, partly because of uncertainty about the changes themselves. A substantial number of areas I inquired about were noted as "subject to negotiation," which suggests flexibility but could also mask a lack of transparency to the process. Overall, the uncertainty over deregulation of the Philippine energy market makes it difficult to project very far into the future what the playing field for wind is going to look like. This report is an update to work I produced for NREL in March of 1999.

One particularly interesting development is the aggressive interest being shown by the Philippine National Oil Company (PNOC), which has shown a strong interest in the Northern Luzon area. The reason their interest is noteworthy is that their model of development is similar to that pursued in the geothermal arena, where the government has been the primary owner and developer of the geothermal resource. Private firms have certainly been engaged in the geothermal sector but the private sector's experience with PNOC has been mixed at best. If PNOC is successful, it may make it more difficult for private wind developers to move projects forward on their own, particularly if those projects do not include a government "share." Still, PNOC's actions also have the potential to move wind development forward where otherwise it might stagnate.

The policy stage for wind energy in the Philippines is set by the claim of the government on wind as a "state" natural resource, much as has been the case with geothermal. This does create some uncertainty about the private sector's rights to the resource under purely private transactions. In transactions with the government, particularly those involving government land and a government "share," the private sector's rights are spelled out fairly clearly.

There appear to be four basic pathways at the moment for selling wind-generated electricity:

1. A joint venture with PNOC Energy Development Corporation (EDC) for sites in Northern Luzon [PNOC contracts with the National Power Corporation (NPC)]
2. Sell power directly to NPC
3. Sell power to Meralco (the incumbent utility in Metro Manila) if the site is within Meralco's service area

4. Sell power to other credit-worthy private companies.

Executive Order 462 apparently applies to all of these options. In addition to establishing standard framework for development of renewable energy projects, EO 462 essentially gives the government the right to a share of the revenues of any Ocean, Solar or Wind (OSW) project in return for certain protections (primarily exclusive development rights and a relatively predictable process) and a long-term contract (up to 25 years, renewable for another 25 years).[1] While private transactions can occur that do not involve the government, there is still a strong "preference" for production-sharing agreements in the conduct of large projects for bulk electricity generation. Smaller projects for remote generation in the provinces are encouraged to be private transactions.

Energy Regulation 1-95 (ER-95) is the other principal regulation that governs how wind is treated in the Philippines. Several major changes were made to this regulation last year[2]:

1. Companies wishing to invest in NRE (New and Renewable Energy) generation facilities need not show a 5-year company track record as long as the project is for self-generation purposes, or the technology being proposed has already achieved commercial status and is adaptable to local conditions, among others.
2. Meeting the requirement on spinning reserve is now easier because it is now subject to negotiation.
3. NRE facilities, including hybrid systems using NRE in combination with fossil fuels, are exempt from the 60% minimum thermal efficiency standard.
4. A long-term power supply agreement with NPC is no longer necessary for NRE projects.

The last of these changes essentially reduces government oversight of private contracts. NPC may still enter into long-term agreements, although the desirability of doing so is reduced by the uncertainty over the nature of deregulation and the expected privatization of NPC. Potentially, the most significant of these changes is the relaxed requirement on spinning reserve, which would have been heavily burdensome for wind projects. The degree of significance is uncertain, however, because the rule now says that it will be handled on a case-by-case basis. This could mean that reserve requirements could still be excessively burdensome. For projects on remote islands, where preferential pricing is in place for projects that save fuel and provide electricity in nonelectrified or under-electrified areas, it is important that "hybrid" configurations will be allowed. Previous rules eliminated the preferential pricing if back-up conventional generation was used.

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[1] All projects on government land must include production sharing, but projects of private property are "preferred" to be production-sharing agreements.

[2] Amendments to Energy Regulation (ER)1-95 dated January 2, 1995, entitled "Rules and Regulations Implementing Executive Order No. 215 - An Order Amending Presidential Decree No. 40 and Allowing the Private Sector to Generate Electricity."

A significant change to EO 462 has also been elimination of the shared revenue requirement from the "first project" of a given developer. Clearly, the Philippine government recognized that revenue sharing could inhibit wind project development. A cap has apparently been put on the government share of such projects in any case. For geothermal, the government share was as much as 60% of revenues. For wind and other renewables, the share is expected to be in the range of 15%, although it has been clarified to apply to only net revenues (gross revenues minus operating and maintenance costs). An additional help is the fact that the government's share is limited by the potential impact on prices to consumers, since the government share cannot result in a cost higher than what consumers are paying. Of course, this would require that the wind project be below the cost of other resources that are supplying that power, which may not be the case. The key will be whether or not the initial projects are of sufficient size to achieve optimal economics and attract private-sector interest.

NPC does say that wind would be treated "as available" or as "must run" technology, but I have not seen that in writing (formally, that is, otherwise only in personal communication with NPC staff). Pricing is a significant issue, and wind must compete directly with other technologies without the benefit of any incentives (other than the income tax holiday discussed elsewhere). Pricing is at "avoided cost," and they say that wind is subject to "economic dispatch," which is in conflict with being accorded "must run" status. NPC notes that a wind project (or any other eligible renewable energy project) could be accorded priority dispatch if it meets any of the following:

1. Competitive generation bid price (if NRE is better than existing power purchasing agreement [PPA])
2. A government policy to accommodate NRE in the main grids
3. The project has bilateral contract with distribution utilities (or specific market - will just pay wheeling charges).

The only policy to accommodate renewable energy in the main grids at the moment is that they will take a competitive renewable project even though they still have surplus generating capacity. The general response is that NPC's pricing policy for wind is a matter for negotiation, so it is difficult to make any definitive statement about what NPC would pay for wind power.

Philippine equity of 60% is still required for projects involving OSW. This will continue to be a significant issue for many foreign developers.

Tax incentives are somewhat more limited now, particularly the elimination of the exemption of import duties on capital equipment, but this applies to virtually all sectors and is not targeted at wind. For "pioneering" projects (first of a kind and an unspecified amount of follow-up projects for renewable energy), there is still a 6-year exemption from income tax. Since many wind projects won't generate positive income in the first years, this incentive may be of limited help.

NPC apparently will not offer a "take or pay" type contract for a large wind farm. There are also no new incentives for wind energy projects. A draft power purchase agreement is being circulated, although it deals specifically with remote power generation in the provinces. I didn't have time to read it very carefully, but it appears to have been given a great deal of careful thought (at least by whoever prepared it, which may be the project proponent).

One matter that has been addressed, but where gaps may still exist, is wind rights. EO 462 does recognize "first use" rights, which is a somewhat indirect way of addressing wind rights, but projects not covered by EO 462 may find it difficult to establish wind rights where adjoining land can be used for a variety of commercial or industrial purposes. Explicit recognition of wind rights may be necessary at some point in the future.

Another concern is the policy of "equal misery" when NPC's grids are down and unable to accept power. That policy can make it difficult to get financing for a private project because of the uncertainty involved in the operation of the Philippine grids, particularly due to the frequent typhoons. NPC is considering making this policy even stricter (more injurious to project proponents) because it is believed that the current policy is costing NPC too much. This would be a significant concern to any Independent Power Project proponent.

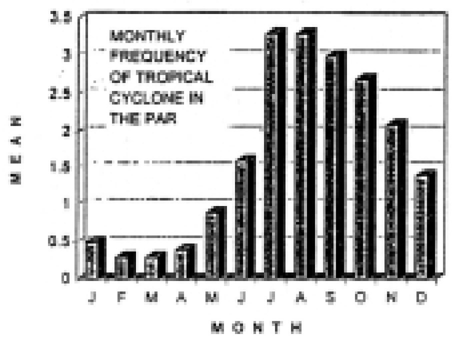
Other matters that haven't been dealt with are tariff denomination or indexing. Particularly given the weakness of the peso, this will be a matter of concern to developers.

Overall, the policy environment for wind has improved, but the specter of deregulation is hovering over the power sector. NPC is renegotiating many of its existing contracts and wants to be considered a "buyer of last resort" for project proponents. It is unclear how wind will fair, although a variety of renewable-energy-friendly elements have been included in one or more versions of the main restructuring bills that have been put forward. The power capacity surplus has not abated either, meaning that there may be less motivation to push the use of indigenous renewable energy resources. On the other hand, it is clear that the major price increases for natural gas and petroleum have hit the Philippines power sector hard and have the attention of policy makers.

Appendix B

DEPARTMENT OF SCIENCE AND TECHNOLOGY
P A G A S A

Climatology and Agrometeorology branch
Climate Change,Drought and Early Warning and Monitoring Center



TROPICAL CYCLONE STATISTICS
(From 1948 to 1998 - 51 Year Period)

Issued January 3, 1999
vcm :.:

TABLE V: FREQUENCY OF TROPICAL CYCLONE PASSAGE OVER PROVINCES
(FROM 1948 TO 1998 - 51 YEAR PERIOD)

PROVINCE	TD		TS		TY		TOTAL	O - A	RANK
		MEAN		MEAN		MEAN		MEAN	
ABRA	8	0.16	19	0.38	37	0.74	64	1.28	6
AGUSAN DEL NORTE	7	0.14	7	0.14	11	0.22	25	0.50	36
AGUSAN DEL SUR	7	0.14	4	0.08	3	0.06	14	0.28	52
AKLAN	2	0.04	2	0.04	8	0.16	12	0.24	54
ALBAY	10	0.20	11	0.22	23	0.46	44	0.88	17
ANTIQUE	6	0.12	13	0.26	21	0.42	40	0.80	18
AURORA	12	0.24	20	0.40	41	0.82	73	1.46	4
BATAAN	3	0.06	8	0.16	11	0.22	22	0.44	41
BATANES	15	0.30	20	0.40	67	1.34	102	2.04	1
BATANGAS	4	0.08	13	0.26	15	0.30	32	0.64	29
BENGUET	5	0.10	11	0.22	14	0.28	30	0.60	32
BOHOL	5	0.10	5	0.10	17	0.34	27	0.54	33
BUKIDNON	1	0.02	3	0.06	0	0.00	4	0.08	57
BULACAN	5	0.10	7	0.14	9	0.18	21	0.42	43
CAGAYAN	12	0.24	28	0.56	55	1.10	95	1.90	2
CAMARINES NORTE	5	0.10	11	0.22	11	0.22	27	0.54	34
CAMARINES SUR	9	0.18	15	0.30	26	0.52	50	1.00	13
CAMIGUIN	5	0.10	6	0.12	9	0.18	20	0.40	44
CAPIZ	3	0.06	5	0.10	11	0.22	19	0.38	47
CATANDUANES	4	0.08	11	0.22	16	0.32	31	0.62	31
CAVITE	2	0.04	11	0.22	10	0.20	23	0.46	40
CEBU	8	0.16	16	0.32	26	0.52	50	1.00	15
COTABATO	0	0.00	0	0.00	1	0.02	1	0.02	65
DAVAO DEL NORTE	1	0.02	2	0.04	0	0.00	3	0.06	60
DAVAO DEL SUR	0	0.00	0	0.00	1	0.02	1	0.02	66
DAVAO ORIENTAL	1	0.02	3	0.06	1	0.02	5	0.10	56
IFUGAO	4	0.08	6	0.12	15	0.30	25	0.50	37
ILOCOS NORTE	6	0.12	14	0.28	31	0.62	51	1.02	14
ILOCOS SUR	9	0.18	17	0.34	33	0.66	59	1.18	9
ILOILO	5	0.10	11	0.22	18	0.36	34	0.68	26
ISABELA	11	0.22	20	0.40	24	0.48	55	1.10	11
KALINGA APAYAO	11	0.22	22	0.44	41	0.82	74	1.48	5
LA UNION	4	0.08	8	0.16	15	0.30	27	0.54	35
LAGUNA	2	0.04	10	0.20	6	0.12	18	0.36	48
LANAO DEL NORTE	0	0.00	1	0.02	1	0.02	2	0.04	62
LANAO DEL SUR	0	0.00	1	0.02	1	0.02	2	0.04	63
LEYTE	11	0.22	16	0.32	25	0.50	57	1.04	12
MAGUINDANAO	0	0.00	0	0.00	1	0.02	1	0.02	67
MARINDUQUE	2	0.04	3	0.06	12	0.24	17	0.34	49
MASBATE	6	0.12	15	0.30	30	0.60	51	1.02	16
MINDORO	5	0.10	14	0.28	37	0.74	56	1.12	10
MISAMIS OCCIDENTAL	1	0.02	1	0.02	1	0.02	3	0.06	61
MISAMIS ORIENTAL	2	0.04	2	0.04	0	0.00	4	0.08	58
MT. PROVINCE	3	0.06	4	0.08	9	0.18	16	0.32	51
NEGROS(OCC. & OR.)	7	0.14	13	0.26	21	0.42	41	0.82	19
NORTHERN SAMAR	11	0.22	17	0.34	36	0.72	64	1.28	7
NUEVA ECIJA	4	0.08	13	0.26	20	0.40	37	0.74	23
NUEVA VISCAYA	4	0.08	13	0.26	21	0.42	38	0.76	22
PALAWAN	7	0.14	14	0.28	20	0.40	41	0.82	20
PAMPANGA	5	0.10	8	0.16	9	0.18	22	0.44	42
PANGASINAN	6	0.12	10	0.20	21	0.42	37	0.74	24
QUEZON	14	0.28	23	0.46	39	0.78	76	1.52	3
QUIRINO	6	0.12	6	0.12	22	0.44	34	0.68	27

TABLE V: FREQUENCY OF TROPICAL CYCLONE PASSAGE OVER PROVINCES
(FROM 1948 TO 1998 - 51 YEAR PERIOD)

Continuation of TABLE V

PROVINCE	TD		TS		TY		TOTAL	O - A	RANK
		MEAN		MEAN		MEAN		MEAN	
RIZAL	5	0.10	2	0.04	10	0.20	17	0.34	50
ROMBLON	3	0.06	10	0.20	20	0.40	33	0.66	30
SAMAR(ERN & WRN)	11	0.22	17	0.34	33	0.66	61	1.22	8
SORSOGON	4	0.08	11	0.22	18	0.36	33	0.66	28
SOUTH COTABATO	0	0.00	0	0.00	0	0.00	0	0.00	70
SULU	0	0.00	0	0.00	0	0.00	0	0.00	71
SURIGAO DEL NORTE	5	0.10	8	0.16	11	0.22	24	0.48	39
SURIGAO DEL SUR	7	0.14	3	0.06	3	0.06	13	0.26	53
TARLAC	2	0.04	2	0.04	15	0.30	19	0.38	46
ZAMBALES	7	0.14	9	0.18	19	0.38	35	0.70	25
ZAMBOANGA DEL NORTE	1	0.02	2	0.04	1	0.02	4	0.08	59
ZAMBOANGA DEL SUR	0	0.00	1	0.02	1	0.02	2	0.04	64
ISLANDS									
BILIRAN IS.	3	0.06	8	0.16	9	0.18	20	0.40	45
BURIAS IS.	1	0.02	5	0.10	6	0.12	12	0.24	55
CALAMIAN GROUP	3	0.06	8	0.16	14	0.28	25	0.50	38
POLILLO IS.	9	0.18	9	0.18	20	0.40	38	0.76	21
SIQUIJOR IS.	0	0.00	1	0.02	0	0.00	1	0.02	68
TICAO IS.	0	0.00	0	0.00	1	0.02	1	0.02	69

Appendix C

Figure C-1: Road/golf course construction in an area north of Caliraya pump/storage reservoir. Amenable soil conditions are obvious in addition to sizable earthmoving equipment.

Figure C-2: Ridge top near the northwest corner of Caliraya pump/storage reservoir looking southeast (reservoir can be seen in background). Transmission lines from the generating station are also noticeable.

Figure C-3: Ridge-top view to the west from the Caliraya pump/storage reservoir. Entrances to penstocks are at the end of the reservoir. Low vegetation heights and mild slopes can be seen.

Figure C-4: Ridge-top view to the northwest from the Caliraya pump/storage reservoir. Another ridge to the north with mild tree coverage can be seen running from the center of picture to the right.

Figure C-5: Ridge-top view to the northeast (prevailing wind direction) from the Caliraya pump/storage reservoir. Another ridge can be seen in the distance (with road construction). Transmission lines are noticeable behind trees. The ridges are oriented northwest to southeast, perpendicular to prevailing wind.

Figure C-6: Ridge-top view to the east from the Caliraya pump/storage reservoir. Low tree heights, conducive ridge width, and the access road are apparent.

Figure C-7: Ridge-top view to the south from the Caliraya pump/storage reservoir

Figure C-8: Ridge-top view to the southwest from the Caliraya pump/storage reservoir. An electrical substation associated with the generating station is noticeable.

Figure C-9: New road construction along route to PAGASA station near Samploc

Figure C-10: PAGASA station met tower. Tower is located on east side of building.

Figure C-11: East view from PAGASA station. Complex terrain and multiple mountains are notable.

Figure C-12: Northeast view (prevailing wind direction) from PAGASA station. Undulating ridge top in foreground is a possible turbine placement area.

Figure C-13: North-northeast view from PAGASA station. Undulating ridgeline is again apparent.

Figure C-14: North view from PAGASA station

Figure C-15: West view from PAGASA station

Figure C-16: East view from PAGASA station to met tower

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Appendix D

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Figure D-23: Example of overhead constraints in the areas around Manila

Figure D-24: Earthwork for a resort near the Caliraya evaluation point

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13. ABSTRACT *(Maximum 200 words)*
The U.S. Department of Energy (DOE), through the National Renewable Energy Laboratory (NREL), has been working in partnership with the U.S. Agency for International Development (USAID) in an ongoing process to quantify the Philippine wind energy potential and foster wind farm development. As part of that process, NREL retained Global Energy Concepts, LLC (GEC) to review and update the policy needs as well as develop a site-screening process applicable for the Philippines. GEC worked closely with the Philippines National Power Corporation (NPC) in completing this work. This report provides the results of the policy needs and site selection analyses conducted by GEC.

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